TETRA TECH

March 16, 2015

Mr. James Johnson
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Subject: **Interim Data Summary of Radiological Parameters Analyzed During Ongoing Baseline Off-Site Air Monitoring**
West Lake Landfill Site, Bridgeton, Missouri
CERCLIS ID: MOD079900932
EPA Region 7, START 4, Contract No. EP-S7-13-06, Task Order No. 0058
Task Monitor: James Johnson, On-Scene Coordinator

Dear Mr. Johnson:

Tetra Tech, Inc. is submitting the attached Interim Data Summary Report regarding radiological parameters assessed during ongoing air monitoring at locations off site of the West Lake Landfill site (WLLS) in Bridgeton, Missouri. This monitoring is occurring during a baseline period prior to start of construction of an isolation barrier at WLLS. If you have any questions or comments, please contact me at (816) 412-1775.

Sincerely,

For Robert Monnig, PE
START Project Manager

Ted Faile, PG, CHMM
START Program Manager

Enclosures

cc: Debra Dorsey, START Project Officer (cover letter only)

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INTERIM DATA SUMMARY OF ONGOING BASELINE OFF-SITE AIR MONITORING RADIOLOGICAL PARAMETERS

WEST LAKE LANDFILL SITE
BRIDGETON, MISSOURI
CERCLIS ID: MOD079900932

Superfund Technical Assessment and Response Team (START) 4
Contract No. EP-S7-13-06, Task Order No. 0058

Prepared For:

U.S. Environmental Protection Agency
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March 16, 2015

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EXECUTIVE SUMMARY

The Tetra Tech, Inc. (Tetra Tech) Superfund Technical Assessment and Response Team (START) is assisting the U.S. Environmental Protection Agency (EPA) with baseline monitoring at off-site locations around the West Lake Landfill site (WLLS) in Bridgeton, Missouri, during a pre-construction, baseline period prior to initiation of construction of a planned isolation barrier at WLLS. This air monitoring will provide data for use to (1) evaluate pre-construction concentrations of chemical and radiological parameters of potential concern in outdoor air, and (2) optimize the sampling and monitoring plan for off-site air monitoring to occur during construction of the isolation barrier. During barrier construction, air monitoring will occur to address concerns that construction operations at WLLS could impact human health and the environment via release to ambient air of solid waste landfill gases of concern or of particulates with radiologically-impacted materials (RIM). This interim report summarizes data sets of radiological parameters acquired from the start of monitoring to January-February 2015 and supersedes the previous interim report for radiological parameters dated January 19, 2015.

West Lake Landfill is an approximately 200-acre property that includes several closed solid waste landfill units that accepted wastes for landfilling from the 1940s or 1950s through 2004, plus a solid waste transfer station, a concrete plant, and an asphalt batch plant. The WLLS is at 13570 St. Charles Rock Road in Bridgeton, St. Louis County, Missouri, approximately 1 mile north of the intersection of Interstate 70 and Interstate 270. The WLLS was used for limestone quarrying and crushing operations from 1939 through 1988. Beginning in the late 1940s or early 1950s, portions of the quarried areas and adjacent areas were used for landfilling municipal refuse, industrial solid wastes, and construction/demolition debris. In 1973, approximately 8,700 tons of leached barium sulfate residues (a remnant from the Manhattan Engineer District/Atomic Energy Commission project) were reportedly mixed with approximately 39,000 tons of soil from the 9200 Latty Avenue site in Hazelwood, Missouri, transported to the WLLS, and used as daily or intermediate cover material. In December 2004, the Bridgeton Sanitary Landfill—the last landfill unit at WLLS to receive solid waste—stopped receiving waste pursuant to an agreement with the City of St. Louis to reduce potential for birds to interfere with Lambert Field International Airport operations. In December 2010, Bridgeton Landfill detected changes—elevated temperatures and elevated carbon monoxide levels—in its landfill gas extraction system in use at the South Quarry of the Bridgeton Sanitary Landfill portion of the WLLS (a landfill portion not associated with known RIM). Further investigation indicated that the South Quarry Pit landfill was undergoing an exothermic subsurface smoldering event (SSE). In 2013, potentially responsible parties committed to constructing an isolation barrier that would separate the landfill portion undergoing the SSE from the RIM-containing area (EPA 2014).

EPA and START began setup of five off-site monitoring stations in April 2014 with monitoring and sampling devices (including particulate air samplers, RAE Systems AreaRAEs, Saphymo GammaTRACERs, electret ion chamber radon detectors, and optically stimulated luminescent dosimeters) and a wireless remote monitoring network. Since April/May 2014, ongoing baseline period off-site air monitoring and sampling have occurred at the following monitoring stations according to the approved quality assurance project plan (QAPP) (Tetra Tech 2014a):

Station 1 – Robertson Fire Protection District Station 2, 3820 Taussig Rd., Bridgeton, Missouri

Station 2 – Pattonville Fire Department District, 13900 St Charles Rock Rd., Bridgeton, Missouri

Station 3 – Pattonville Fire Department District Station 2, 3365 McKelvey Rd., Bridgeton, Missouri

Station 4 – Spanish Village Park, 12827 Spanish Village Dr., Bridgeton, Missouri

Station 5 – St. Charles Fire Department Station #2, 1550 S. Main St., St. Charles, Missouri.

The Station 1 through 4 locations were selected primarily for their proximate positions around WLLS (these stations are approximately 0.3 to 1 mile from WLLS, in various directions from WLLS). Station 5, designated as a reference (or background) station, is farther away from WLLS than the other stations, but still within the general vicinity so as to be representative of the North St. Louis County and eastern St. Charles County area.

The radiation air monitoring is measuring three forms of ionizing radiation (alpha, beta and gamma) by specific exposure pathways (dust/particulate, radon, and ambient gamma exposure). The monitoring includes weekly laboratory analysis of particulate filters, weekly radon monitoring with electrets, monthly deployments of environmental dosimeters for gamma exposure, and continuous gamma exposure rate monitoring. This interim report summarizes the radiation air monitoring and sampling results from the start of monitoring to January-February 2015. Overall, the radiation air monitoring and sampling results appear typical of an outdoor environment. The following are specific interim observations regarding the radiological parameters being measured at the five air monitoring stations off site of WLLS:

Radionuclides on Airborne Particulates

Airborne particulates are collected onto glass fiber filter media by use of high-volume air samplers. The air filters are submitted for laboratory analyses for gross alpha, gross beta, gamma-emitting radionuclides, isotopic uranium, isotopic thorium, and total alpha-emitting radium. The air filter results evaluated in this interim report are gross alpha/beta, uranium-238 (^{238}U), ^{230}Th, and total alpha-emitting radium (including ^{226}Ra). The medians and distributions of these parameters appear to be similar among the five monitoring stations. Two statistics tests—the Kruskal-Wallis and Friedman tests—were used to test for differences in concentrations of gross alpha/beta, ^{238}U, ^{230}Th, and total alpha-emitting radium (including ^{226}Ra) among the five monitoring stations. The Kruskal-Wallis test did not identify significant differences in the mean/median characteristics among the five monitoring stations for the data examined, and the Friedman test found no indication that one station had yielded larger or smaller measurements than any other station.

Radon

Radon (^{222}Rn) has been identified as a radiological parameter of interest because it is a decay product of ^{226}Ra, a radionuclide of concern at the WLLS. Radon is also generated by decay of ^{226}Ra naturally occurring in soil and rock, and a significant portion of this radon is naturally released from the ground into the atmosphere because, as a noble gas, radon becomes unbound to soil and rock. Average weekly ^{222}Rn concentrations are measured at the five off-monitoring stations by use of electret ion chamber radon detectors (Rad Elec E-PERM®). Examination of the ^{222}Rn box plots appears to show similar median ^{222}Rn concentrations among the five monitoring stations (although results from statistical tests used to evaluate the data suggest that ^{222}Rn measurements at Stations 2 and 4 tend to be smaller than those at the other stations).

Exposure Rate Measurements

Hourly exposure rate measurements are obtained by use of Saphymo GammaTRACERs exposure rate monitors installed at each of the five off-site monitoring stations. Although a release of RIM via airborne particulates from the WLLS is not anticipated to yield an off-site external gamma exposure rate distinguishable from background variability, acquisition of these data are occurring for possible use as a reference for future monitoring campaigns that will include exposure rate measurements. Review of the GammaTRACER data revealed that exposure rates at the five monitoring stations fluctuated around 10 microroentgens per hour (μR/hr)—a typical exposure rate within outdoor environments (National Council on Radiation Protection and Measurements [NCRP] 1987)—with exposure rates at some stations tending slightly higher or lower than 10 μR/hr (an expected outcome due to variations in local geology and surface conditions). Notably, numerous temporary spikes in the exposure rate readings corresponded to precipitation events, indicating likely precipitation scavenging (or washout) of airborne radionuclides (a process whereby radionuclides—primarily radon daughter products—suspended as aerosols in the atmosphere coalesce with precipitation and are transported with the falling precipitation to the ground surface). Overall, the gamma rate measurements appear typical for an outdoor environment.

Environmental Dosimetry

Month-long environmental dosimetry measurements are obtained at the off-site monitoring stations by use of Landauer, Inc. InLight optically stimulated luminescent (OSL) dosimeters to supplement the exposure rate measurements obtained by use of the Saphymo GammaTRACERs. The OSL dosimetry data appear normal for outdoor ambient measurements.

1.0 INTRODUCTION

The Tetra Tech, Inc. (Tetra Tech) Superfund Technical Assessment and Response Team (START) has been tasked by the U.S. Environmental Protection Agency (EPA) to assist with baseline monitoring at off-site locations around the West Lake Landfill site (WLLS) in Bridgeton, Missouri. The monitoring effort began in April 2014 and is ongoing. This interim report summarizes data sets of radiological parameters acquired from the start of monitoring to January-February 2015.

START's tasks have included: (1) assembling and maintaining a network of off-site air monitoring stations with instrumentation and sampling devices to measure radiological and chemical parameters of concern, (2) collecting samples and coordinating laboratory analysis, (3) assisting EPA with data acquisition and management, (4) documenting the off-site air monitoring efforts, and (5) validating/verifying initial screening of the data.

The objective of this report is to present an interim summary of the radiological data acquired, including findings related to data validation, verification, and usability. Tabulated data summaries and plots of the data appear within the relevant report sections. A site figure is in Appendix A. Tabulated sampling results are in Appendix B. Calculations supporting the radon measurements are in Appendix C. Results of statistical analyses are in Appendix D.

2.0 PROBLEM DEFINITION, BACKGROUND, AND SITE DESCRIPTION

EPA is conducting ongoing air monitoring at locations off site of WLLS during a pre-construction, baseline period prior to initiation of construction of a planned isolation barrier at WLLS. Air monitoring during the baseline period will provide data for use to (1) evaluate pre-construction concentrations of chemical and radiological parameters of potential concern in outdoor air, and (2) optimize the sampling and monitoring plan for the off-site air monitoring to occur during construction of the isolation barrier. During barrier construction, air monitoring will occur to address concerns that operations at WLLS could impact human health and the environment via release to ambient air of solid waste landfill gases of concern or of particulates with radiologically-impacted materials (RIM).

West Lake Landfill is an approximately 200-acre property including several closed solid waste landfill units that accepted wastes for landfilling from the 1940s or 1950s through 2004, plus a solid waste transfer station, a concrete plant, and an asphalt batch plant. The WLLS is at 13570 St. Charles Rock Road in Bridgeton, St. Louis County, Missouri, approximately 1 mile north of the intersection of Interstate 70 and Interstate 270 (see Appendix A, Figure 1). WLLS was used for limestone quarrying and crushing operations from 1939 through 1988. Beginning in the late 1940s or early 1950s, portions of the quarried areas and adjacent areas were used for landfilling municipal refuse, industrial solid wastes, and construction/demolition debris. In 1973, approximately 8,700 tons of leached barium sulfate residues (a remnant from the Manhattan Engineer District/Atomic Energy Commission project) were reportedly mixed with approximately 39,000 tons of soil from the 9200 Latty Avenue site in Hazelwood, Missouri, transported to the WLLS, and used as daily or intermediate cover material. In December 2004, the Bridgeton Sanitary Landfill—the last landfill unit at WLLS to receive solid waste—stopped receiving waste pursuant to an agreement with the City of St. Louis to reduce potential for birds to interfere with Lambert Field International Airport operations. In December 2010, Bridgeton Landfill detected changes—elevated temperatures and elevated carbon monoxide levels—in its landfill gas extraction system operating at the South Quarry of the Bridgeton Sanitary Landfill portion of the WLLS (a landfill portion not associated with known RIM). Further investigation indicated that the South Quarry Pit landfill was undergoing an exothermic subsurface smoldering event (SSE). In 2013, potentially responsible parties committed to constructing an isolation barrier that would separate the landfill portion undergoing the SSE from the RIM-containing area (EPA 2014).

3.0 SAMPLING STRATEGY AND METHODOLOGY

EPA and START began setup of the five off-site monitoring stations in April 2014; these activities included installations of electrical service, instrument weather housings, monitoring and sampling devices (including particulate air samplers, RAE Systems AreaRAEs, Saphymo GammaTRACERs, electret ion chamber radon detectors, and optically stimulated luminescent [OSL] dosimeters), and a wireless remote monitoring network. Since April/May 2014, ongoing baseline period off-site air monitoring and sampling have occurred at the following monitoring stations according the approved quality assurance project plan (QAPP) (Tetra Tech 2014a) (see Appendix A, Figure 1):

Station 1 – Robertson Fire Protection District Station 2, 3820 Taussig Rd., Bridgeton, Missouri

Station 2 – Pattonville Fire Department District, 13900 St Charles Rock Rd., Bridgeton, Missouri

Station 3 – Pattonville Fire Department District Station 2, 3365 McKelvey Rd., Bridgeton, Missouri

Station 4 – Spanish Village Park, 12827 Spanish Village Dr., Bridgeton, Missouri

Station 5 – St. Charles Fire Department Station #2, 1550 S. Main St., St. Charles, Missouri.

The Station 1 through 4 locations were selected primarily for their proximate positions around WLLS (these stations are approximately 0.3 to 1 mile from WLLS, in various directions from WLLS). Station 5 was designated as a reference (or background) station, and its location was selected according to the criterion that it be frequently upwind of WLLS and farther away from WLLS than the other stations, but still within the general vicinity so as to be representative of the North St. Louis County and eastern St. Charles County area. Station 5 is farther away from WLLS than the other stations (approximately 2.3 miles west of WLLS), frequently upwind of WLLS, roughly twice the distance from WLLS than the next closest station (Station 3), and within the general vicinity of the North St. Louis County and eastern St. Charles County area so as to be representative of that area (see wind rose presented in Appendix A, Figure 1).

The radiological parameters of potential concern were identified in the QAPP (Tetra Tech 2014a) based on historical information regarding the site and program experience with similar types of sites. During the baseline sampling period, assessment of presence of naturally occurring alpha-, beta-, and gamma-emitting radionuclides on airborne particulates is occurring. The radionuclides of potential concern based on characteristics of the West Lake RIM are thorium-230 (^{230}Th), radium-226 (^{226}Ra), and radon (^{222}Rn). Assessments of gross alpha, beta, and gamma activities (including environmental dosimetry measurements) also are occurring at each monitoring station.

Sampling is consistent with EPA methods and standard operating procedures (SOP) specified in the approved QAPP (Tetra Tech 2014a). Presented in Section 4.0 with the interim data summaries are descriptions of the project-specific sampling methods associated with the various radiological parameters assessed.

4.0 INTERIM SUMMARY AND EVALUATION OF RADIOLOGICAL DATA

The following sections present interim data summaries of the radionuclide parameters assessed during the ongoing baseline monitoring period, including time series and box plots of the data, and results of statistical analyses. Tabulated data are in Appendix B.

4.1 RADIONUCLIDES ON AIRBORNE PARTICULATES

Presence of naturally occurring alpha-, beta-, and gamma-emitting radionuclides on airborne particulates is being assessed. Based on characteristics of the West Lake Landfill RIM, the radionuclides of potential concern measurable via sampling and analyzing airborne particulates are uranium-238 (^{238}U), ^{230}Th, and ^{226}Ra.

4.1.1 Sampling Procedure

To determine airborne concentrations of radionuclides transported via airborne particulates, airborne particulates are collected onto 2-inch-diameter borosilicate glass fiber filter media by use of high-volume air samplers (RADeCO Model HD28 or equivalent air sampler). One air sampler is operated at each off-site monitoring station to collect airborne particulates continuously onto the filter media for a duration of 7 days. The air samplers are operated at a flow rate of at least 2.0 cubic feet per minute to yield a minimum air sample volume of 20,160 cubic feet (571 cubic meters [m^3]). At the end of the sampling period, the sampled filter is submitted for laboratory analysis, a new filter is installed, and a new 7-day sampling period begins.

The filters are analyzed by TestAmerica of Earth City, Missouri, for gross alpha, gross beta, gamma-emitting radionuclides, isotopic uranium, isotopic thorium, and total alpha-emitting radium. The laboratory results are reported as total activity (in picoCuries [pCi]) per filter. Total air volume drawn through the filter is recorded by the field sampler at the time of filter collection. Air concentrations are calculated by dividing the per filter total activity (in pCi) by the volume of air drawn through the filter (in m^3) to yield an air concentration in units of pCi/m^3.

4.1.2 Data Validation, Verification, and Usability

As laboratory analytical reports are received for the airborne particulate radionuclide analysis, START reviews and qualifies the data according to EPA Contract Laboratory Program guidelines (EPA 2008), the *Multi-Agency Radiological Laboratory Analytical Protocols Manual* (EPA 2004), and other criteria specified in the applicable methods. Findings of these reviews are documented in a data validation report that is appended to each analytical laboratory report and included in the data deliverable packages (see Tetra Tech 2014b, c, d, e, f and Tetra Tech 2015a, b). Suggested qualifications to the data from START's review are indicated by qualifier flags that accompany the data presented herein. Overall, review of the laboratory analytical data packages indicated that quality of the airborne particulate data was acceptable and usable as qualified for the intended purposes of those data.

4.1.3 Gross Alpha Results and Evaluation

The following describes gross alpha results from weekly air filter samples collected from May 8, 2014 through February 11, 2015.

Summary Statistics

Table 1 lists frequency of detection and minimum, median, and maximum gross alpha concentrations.

TABLE 1

SUMMARY STATISTICS OF GROSS ALPHA RESULTS

Summary Statistic	Station 1	Station 2	Station 3	Station 4	Station 5 (background)
Detections[1]	32/40	32/40	27/40	26/40	28/40
Minimum Concentration[2]	1.99E-04 U	1.93E-04 U	1.02E-04 U	1.17E-04 U	1.10E-04 U
Median Concentration[3]	6.17E-04	6.25E-04	6.71E-04	6.11E-04	6.61E-04
Maximum Concentration[4]	1.63E-03 J	1.68E-03 J	1.58E-03 J	1.38E-03 J	1.65E-03 J

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

J Indicates an estimated result
U Indicates a non-detected result

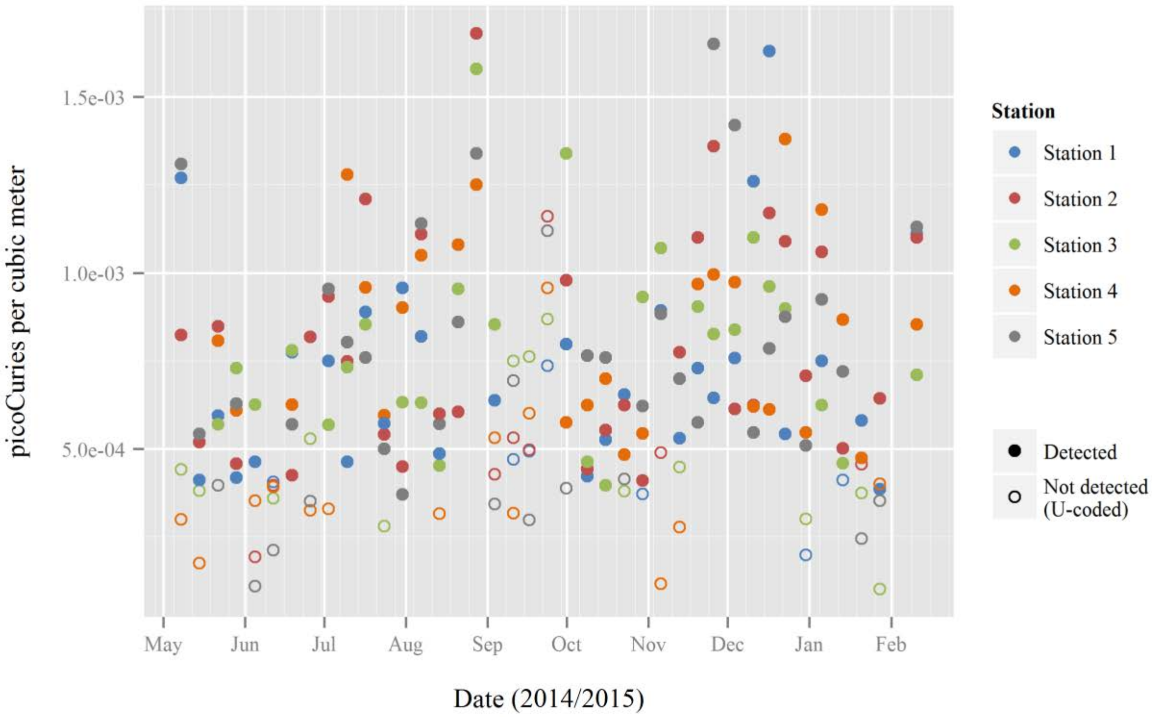
1 Number of detections / number of samples. U-coded results were counted as not detected.
2 Includes lowest reported value among both U-coded and non-U-coded results.
3 Median concentration among U-coded and non-U-coded results.
4 Maximum detected (non-U-coded) concentration.

Time Series Plot

Exhibit 1 is a time series graph of the gross alpha results. This graph shows no discernable trends or patterns in the data.

EXHIBIT 1

TIME SERIES PLOT OF GROSS ALPHA ACTIVITY

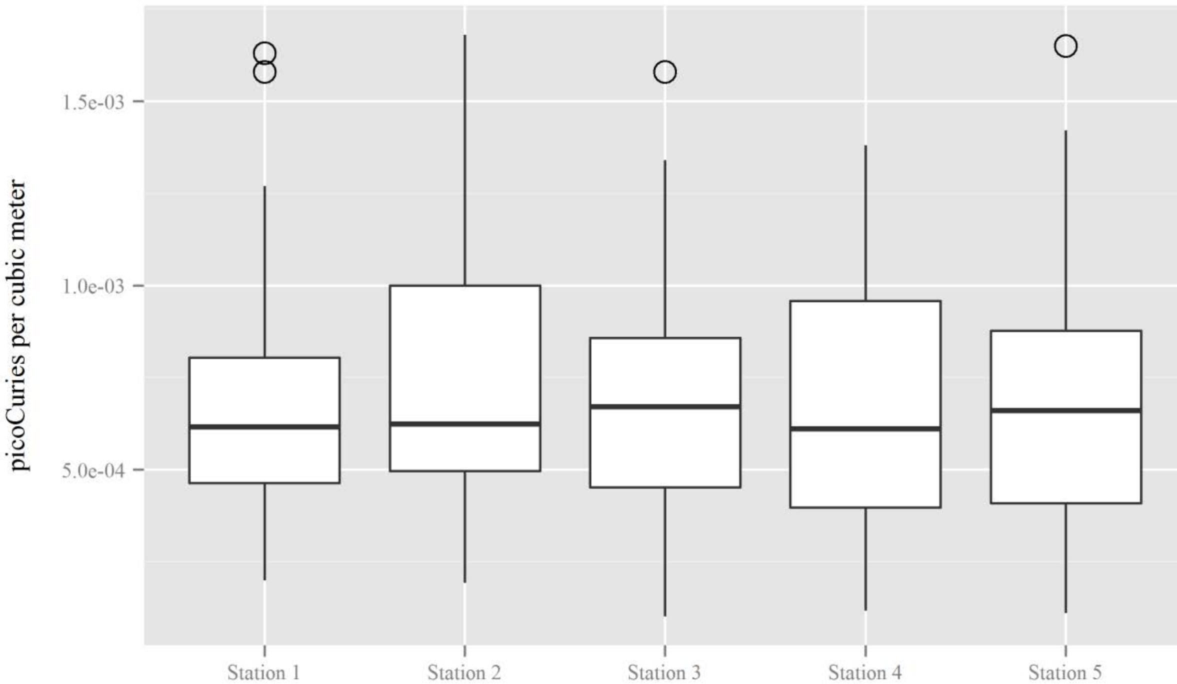


<u>Box Plots</u>

Exhibit 2 shows box plots of the gross alpha results. These plots suggest similar median concentrations and distributions among the five monitoring stations. The box plots suggest several upper end outlier concentrations (indicated by open circles) for Stations 1, 2, and 5. Data users should be aware of these suggested outliers because their representation of the parameter being measured is uncertain. The cause of the suggested outliers in the gross alpha data is unknown, but outliers are often attributed to measurement error or can occur by chance in any distribution. Regarding the suggested outliers in the gross alpha data, one should consider that (1) maximum detected gross alpha concentrations among the five stations were within an order of magnitude (the station maximums ranged from 1.38E-03 to 1.68E-03 pCi/m^3), (2) suggested outliers occurred at multiple stations, and (3) statistical analyses suggest that the median/mean characteristics of the distributions were similar among the five stations, and that no station tended to yield higher or lower results than any other station (see Section 4.1.8).

EXHIBIT 2

BOX PLOTS OF GROSS ALPHA ACTIVITY



Gross Beta Results and Evaluation

The following describes the gross beta results from weekly air filter samples collected from May 8, 2014 through February 11, 2015.

<u>Summary Statistics</u>

Table 2 lists frequency of detection and minimum, median, and maximum gross beta concentrations.

TABLE 2

SUMMARY STATISTICS OF GROSS BETA RESULTS

Summary Statistic	Station 1	Station 2	Station 3	Station 4	Station 5 (reference)
Detections[1]	40/40	40/40	40/40	40/40	40/40
Minimum Concentration	1.15E-02	4.13E-03 J	1.32E-02 J	1.32E-02 J	1.21E-02 J
Median Concentration	1.96E-02	1.96E-02	2.02E-02	2.01E-02	1.91E-02
Maximum Concentration	3.57E-02	3.61E-02	3.88E-02	3.70E-02	3.53E-02

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

J Indicates an estimated result

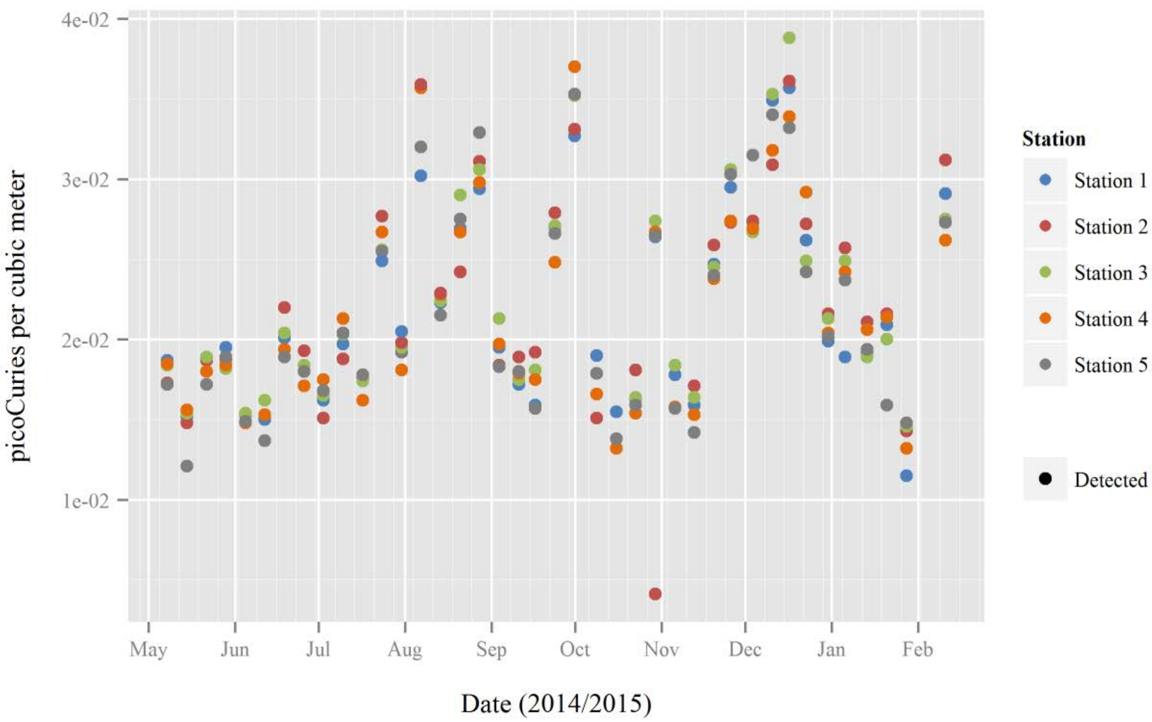
1 Number of detections / number of samples (no gross beta results are U-coded).

Time Series Plot

The gross beta time series plot in Exhibit 3 shows no discernable trends or patterns in the data, except that gross beta results from filters collected during the same week appear to be related by a common component that varies irregularly from week to week. The cause of this is unknown, but possibly this is attributable to naturally occurring, short-lived radon daughters collected onto the filters that variably contribute to the gross beta concentrations (depending on the amount of time between filter collection and analysis allowing for decay).

EXHIBIT 3

TIME SERIES PLOT OF GROSS BETA ACTIVITY

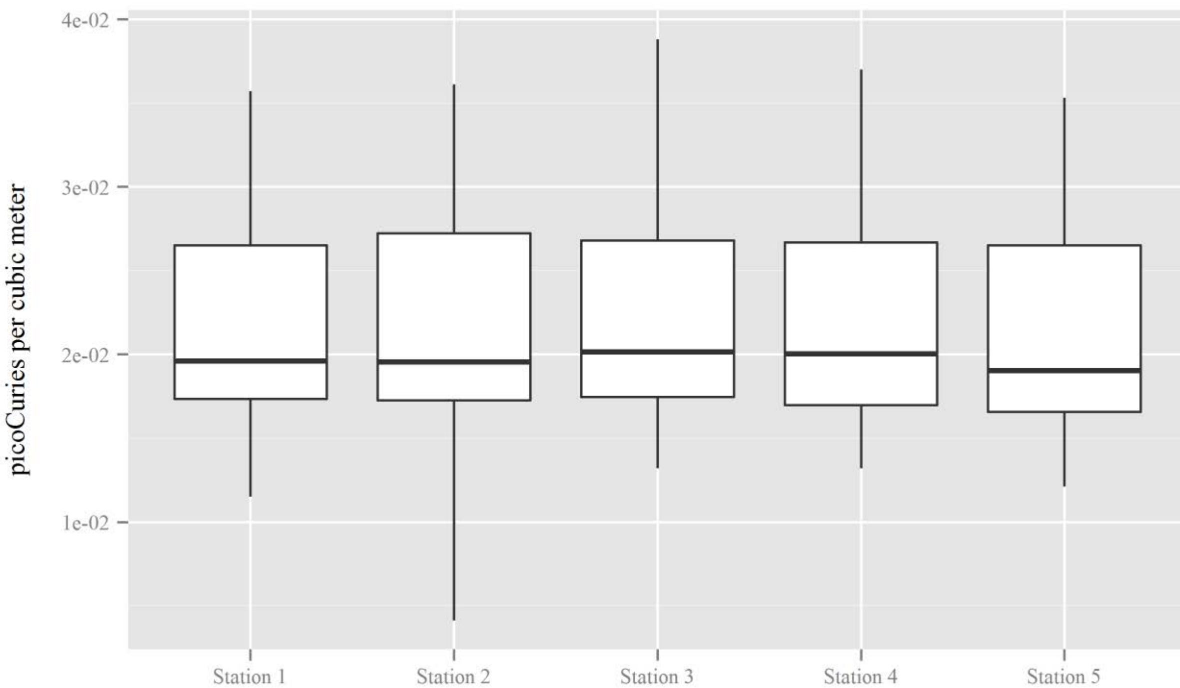


Box Plots

Exhibit 4 shows box plots of the gross beta results. These plots suggest similar median concentrations and distributions among the five monitoring stations and no outlier concentrations are suggested by the boxplots.

EXHIBIT 4

BOX PLOTS OF GROSS BETA ACTIVITY



4.1.4 Uranium-238 Results and Evaluation

The following describes ^{238}U results from weekly air filter samples collected from May 8, 2014 through January 21, 2015.

Summary Statistics

Table 3 lists frequency of detection and minimum, median, and maximum ^{238}U concentrations.

TABLE 3

SUMMARY STATISTICS OF URANIUM-238 RESULTS

Summary Statistic	Station 1	Station 2	Station 3	Station 4	Station 5 (reference)
Detections[1]	17/38	21/38	19/38	12/38	13/38
Minimum Concentration[2]	-4.45E-05 U	-8.55E-05 U	-4.42E-05 U	2.75E-05 U	-2.39E-05 U
Median Concentration[3]	1.02E-04	1.21E-04	1.12E-04	9.03E-05	1.02E-04
Maximum Concentration[4]	6.22E-04 J	9.47E-04 J	3.86E-04 J	3.07E-04 J	1.67E-04 J

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

J Indicates an estimated result
U Indicates a non-detected result

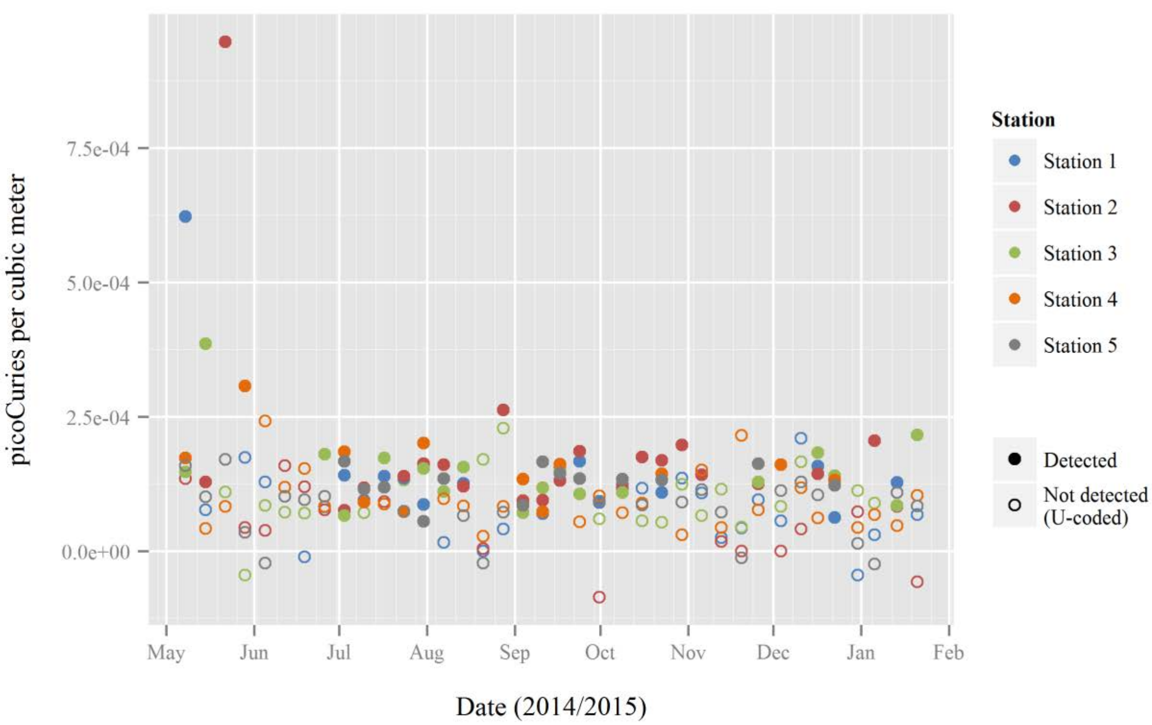
[1] Number of detections / number of samples. U-coded results were counted as not detected.
[2] Includes lowest reported value among both U-coded and non-U-coded results.
[3] Median concentration among U-coded and non-U-coded results.
[4] Maximum detected (non-U-coded) concentration.

Time Series Plot

The time series plot of ^{238}U results in Exhibit 5 shows no discernable trends or patterns in the data.

EXHIBIT 5

TIME SERIES PLOT OF URANIUM-238

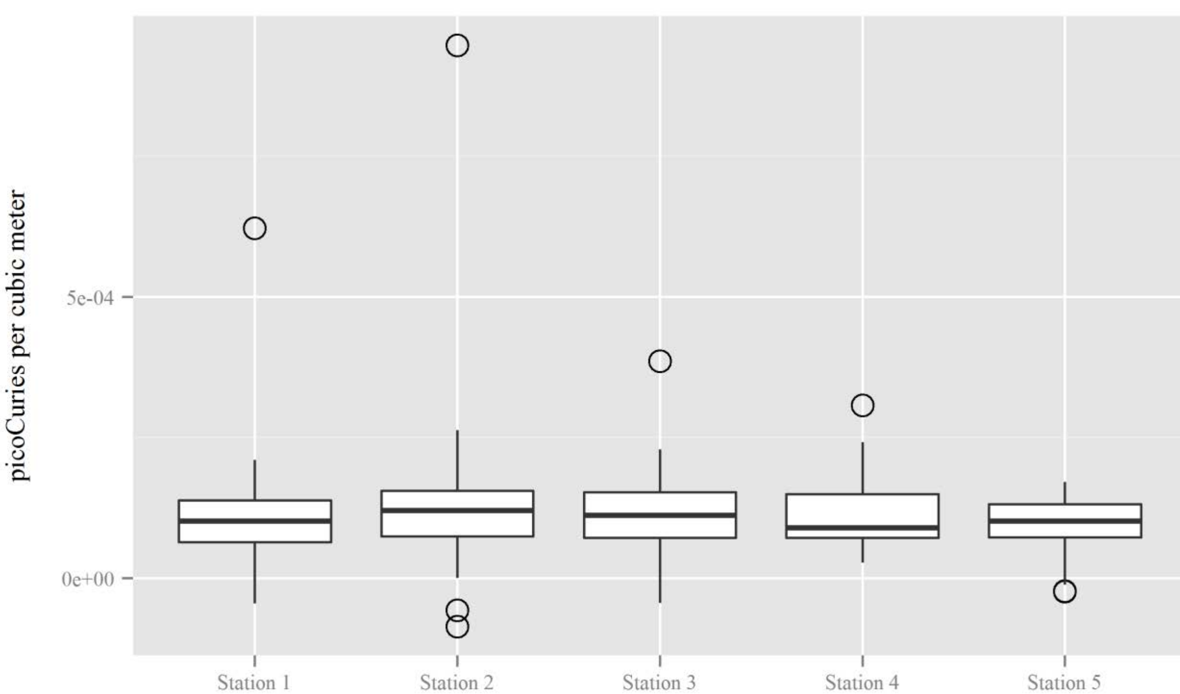


Box Plots

Exhibit 6 shows box plots of the ^{238}U results. As with the gross alpha and beta results, these plots suggest similar median concentrations and distributions among the five monitoring stations. The box plots suggest several upper end outlier concentrations (indicated by open circles) at Stations 1, 2, 3, and 4. Data users should be aware of these suggested outliers because their representation of the parameter being measured is uncertain. The cause of the suggested outliers in the ^{238}U data is unknown, but outliers are often attributed to measurement error or can occur by chance in any distribution. Regarding the suggested outliers in the ^{238}U data, one should consider that (1) maximum detected ^{238}U concentrations among the five stations were within an order of magnitude (the station maximums ranged from 1.67E-04 to 9.47E-04 pCi/m^3), (2) suggested outliers occurred at multiple stations, and (3) statistical analyses suggested that median/mean characteristics of the distributions were similar among the five stations, and that no station tended to yield higher or lower results than any other station (see Section 4.1.8).

EXHIBIT 6

BOX PLOTS OF URANIUM-238 ACTIVITY



4.1.5 Thorium-230 Results and Evaluation

The following describes ^{230}Th results from weekly air filter samples collected from May 8, 2014 through January 21, 2015.

Summary Statistics

Table 4 lists frequency of detection and minimum, median, and maximum ^{230}Th concentrations.

TABLE 4

SUMMARY STATISTICS OF THORIUM-230 RESULTS

Summary Statistic	Station 1	Station 2	Station 3	Station 4	Station 5 (reference)
Detections[1]	37/38	33/38	36/38	35/38	36/38
Minimum Concentration[2]	2.68E-04 J	2.70E-04 J	1.37E-04 J	1.81E-04 J	2.71E-04 U
Median Concentration[3]	4.89E-04	5.71E-04	5.85E-04	5.44E-04	5.32E-04
Maximum Concentration[4]	4.37E-03	1.36E-03 J	8.86E-04 J	1.29E-03 J	1.99E-03 J

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

J Indicates an estimated result

U Indicates a non-detected result

[1] Number of detections / number of samples. U-coded results were counted as not detected.

[2] Includes lowest reported value among both U-coded and non-U-coded results.

[3] Median concentration among U-coded and non-U-coded results.

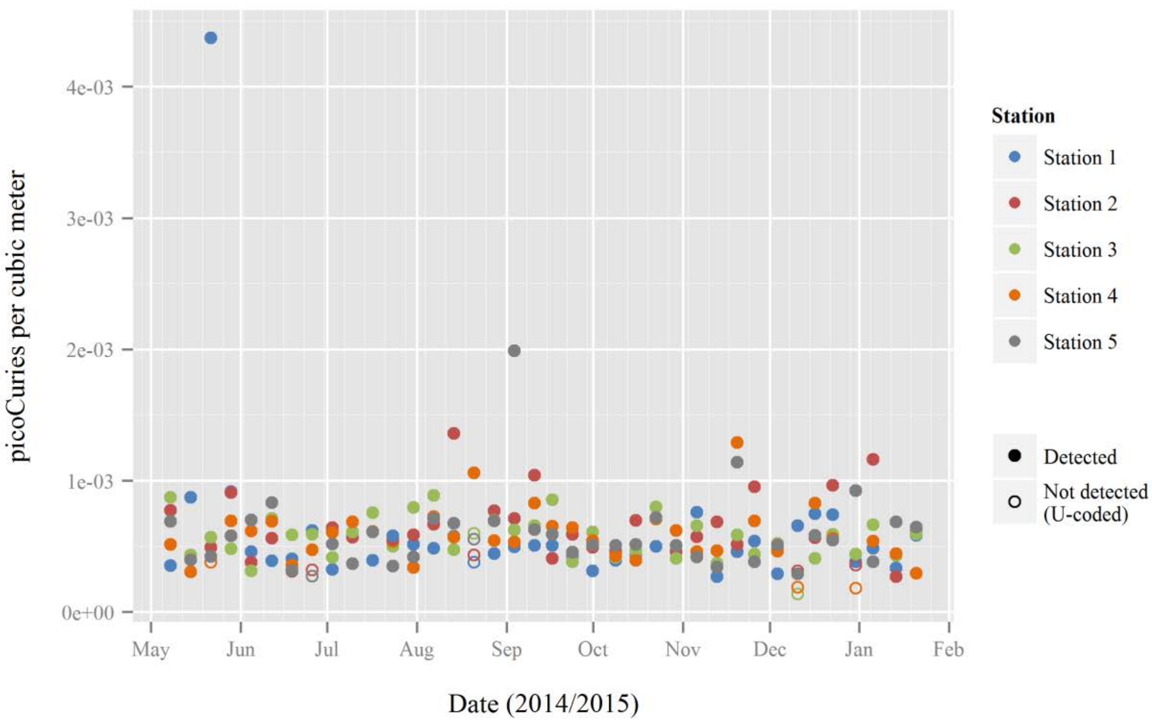
[4] Maximum detected (non-U-coded) concentration.

Time Series Plot

The time series plot of ^{230}Th results in Exhibit 7 shows no discernable trends or patterns in the data.

EXHIBIT 7

TIME SERIES PLOT OF THORIUM-230

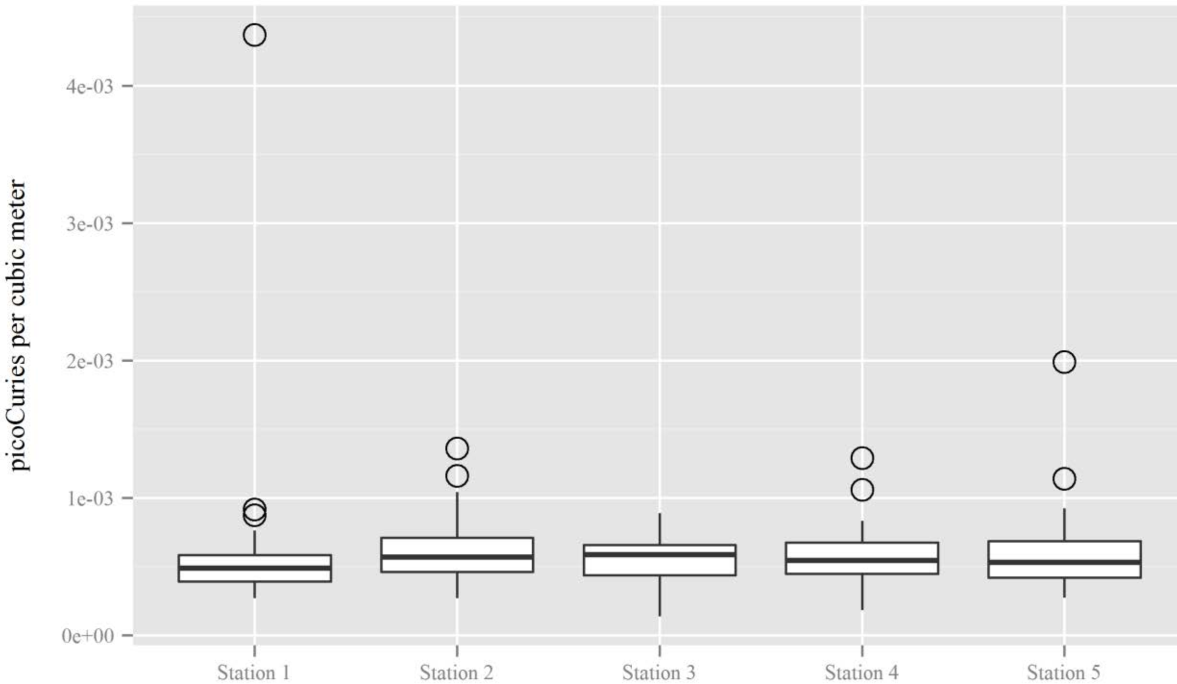


<u>Box Plots</u>

Exhibit 8 shows box plots of the ^{230}Th results. As with the aforementioned gross alpha/beta and ^{238}U results, these plots suggest similar median concentrations and distributions among the five monitoring stations. The box plots suggest several upper end outlier concentrations (indicated by open circles) at Stations 1, 2, 4, and 5. Data users should be aware of these suggested outliers because their representation of the parameter being measured is uncertain. The cause of the suggested outliers in the ^{230}Th data is unknown, but outliers are often attributed to measurement error or can occur by chance in any distribution. Regarding the suggested outliers in the ^{230}Th data, one should consider that (1) maximum detected ^{230}Th concentrations among the five stations were within an order of magnitude (the station maximums ranged from 8.86E-04 to 4.37E-03 pCi/m^3), (2) suggested outliers occurred at multiple stations (including Station 5, the reference station), and (3) statistical analyses suggested that the median/mean characteristics of the distributions were similar among the five stations, and that no station tended to have higher or lower results than any other station (see Section 4.1.8).

EXHIBIT 8

BOX PLOTS OF THORIUM-230 ACTIVITY



4.1.6 Total Alpha-Emitting Radium Results and Evaluation

The following describes the total alpha-emitting radium results from weekly air filter samples collected from May 8, 2014 through January 21, 2015. Although the radium isotope of interest for WLLS is ^{226}Ra, as a cost-savings measure and to reduce analysis time, the samples were first analyzed via a method that reports total alpha-emitting radium, which includes the radium isotopes ^{223}Ra, ^{224}Ra, and ^{226}Ra. If a sample yielded a total alpha-emitting radium result exceeding 5 pCi per filter (corresponding to an air concentration of 8.8E-3 pCi/m^3 for the targeted air volume of 571 m^3), that sample was to be re-analyzed via a ^{226}Ra-specific method. However, none of the total alpha-emitting radium results exceeded 5 pCi per filter, although the laboratory mistakenly prepared the samples collected on May 15, 2014, for a ^{226}Ra-specific analysis, and the reported results were ^{226}Ra concentrations (these data are flagged "$_{(226)}$").

<u>Summary Statistics</u>
Table 5 lists frequency of detection and minimum, median, and maximum total alpha-emitting radium concentrations.

TABLE 5

SUMMARY STATISTICS OF TOTAL ALPHA-EMITTING RADIUM RESULTS

Summary Statistic	Station 1	Station 2	Station 3	Station 4	Station 5 (reference)
Detections[1]	3/37	4/37	3/37	2/37	2/37
Minimum Concentration[2]	-2.50E-04 U	-6.83E-04 U	-1.56E-04 U	-4.86E-04 U	-4.34E-04 U
Median Concentration[3]	4.49E-04	4.72E-04	3.50E-04	5.09E-04	3.90E-04
Maximum Concentration[4]	1.10E-03 J	1.80E-03 J	2.01E-03	1.38E-03 J	4.40E-03

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)
J Indicates an estimated result
U Indicates a non-detected result

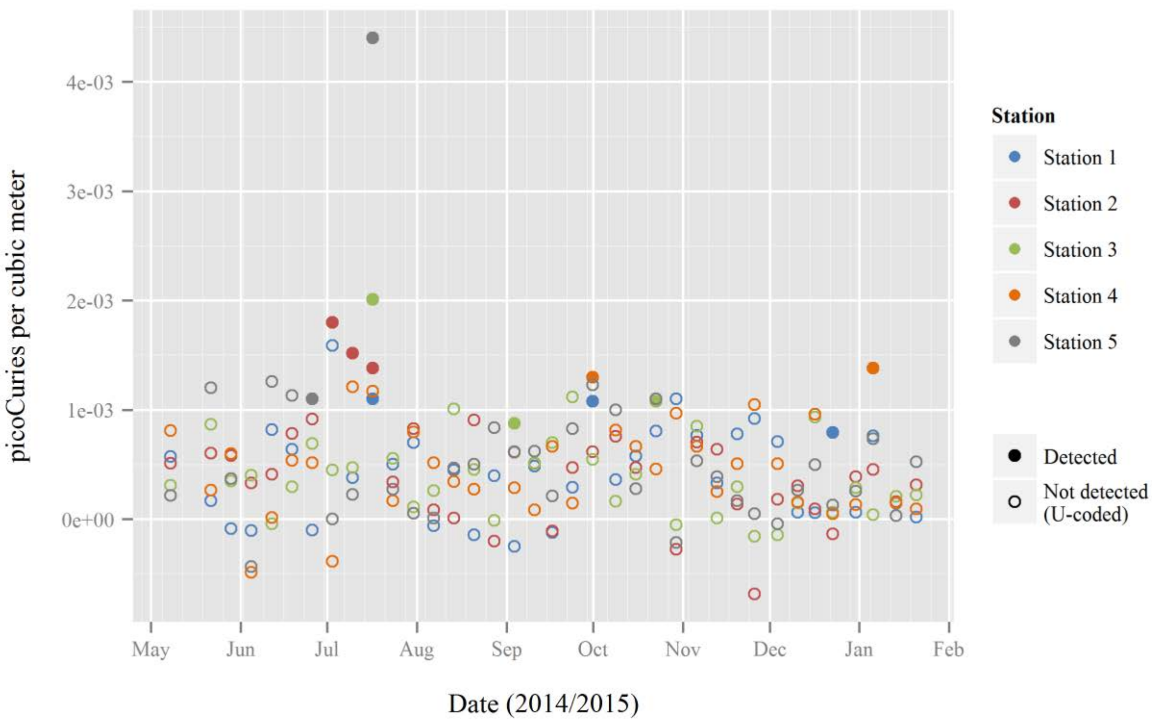
[1] Number of detections / number of samples. U-coded results were counted as not detected.
[2] Includes lowest reported value among both U-coded and non-U-coded results.
[3] Median concentration among U-coded and non-U-coded results.
[4] Maximum detected (non-U-coded) concentration.

Time Series Plot

The total alpha-emitting radium time series plot in Exhibit 9 shows no discernable trends or patterns in the data. Notably, almost 90 percent of the data are U-coded, indicating a non-detect result.

EXHIBIT 9

TIME SERIES PLOT OF TOTAL ALPHA-EMITTING RADIUM

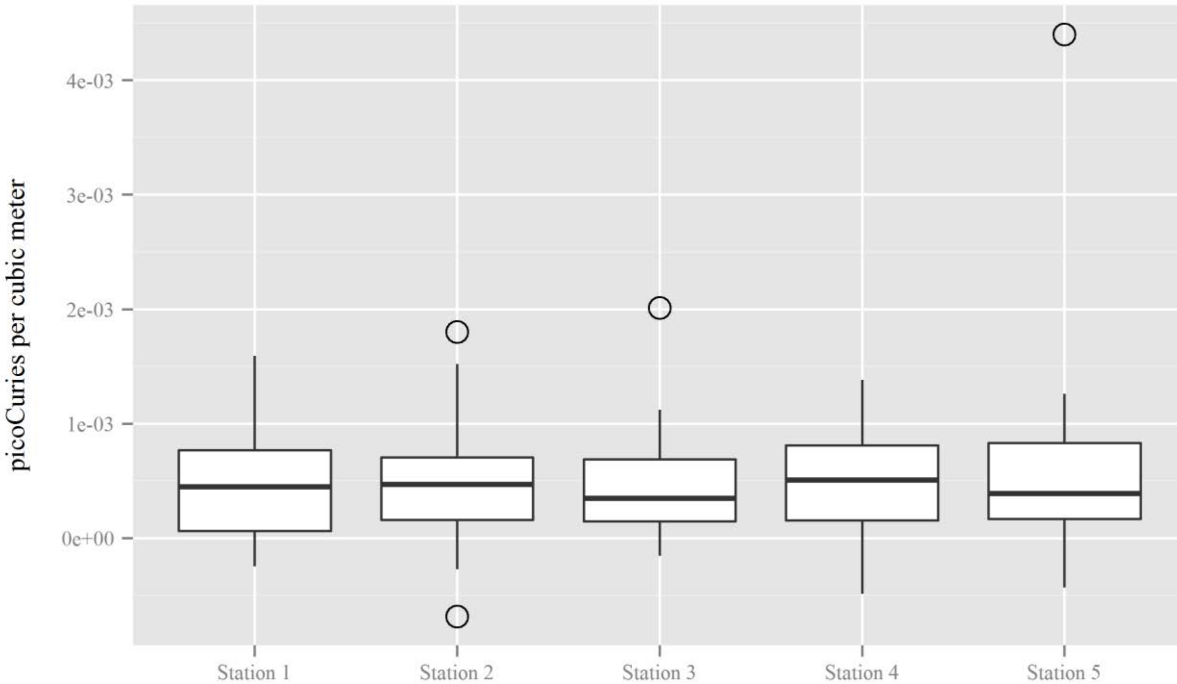


Box Plots

Exhibit 10 shows box plots of the total-alpha emitting radium results; however, utility of these plots is limited because nearly 90 percent of the total-alpha emitting radium results were non-detect (the box plots show both U-coded and non-U-coded results).

EXHIBIT 10

BOX PLOTS OF TOTAL ALPHA-EMITTING RADIUM RESULTS



4.1.7 Statistical Analyses

Two statistics tests—the Kruskal-Wallis and Friedman tests—were used to test for differences in gross alpha/beta results, and concentrations of ^{238}U, ^{230}Th, and total alpha-emitting radium (including ^{226}Ra) among the five monitoring stations. The Kruskal-Wallis and Friedman tests are non-parametric statistical tests that compare multiple treatments (such as the multiple monitoring locations). The Kruskal-Wallis test assumes data sets are independent, whereas the Friedman Rank Sum test accounts for related (or cluster-correlated) data. Because the time-series plots suggested that some data were unrelated (such as the gross-alpha results that showed no obvious clustering from week to week) and some were related (such as the gross-beta results showing obvious clustering from week to week), both tests were used. The data underwent the Kruskal-Wallis and Friedman tests by use of the statistical software package R (see Appendix D for the input data sets, R scripts, and R output). Table 6 summarizes the Kruskal-Wallis and Friedman test results.

The Kruskal-Wallis test did not identify significant differences in mean/median characteristics of the data examined (gross alpha, gross beta, ^{238}U, ^{230}Th, and total alpha-emitting radium) among the five monitoring stations. The Friedman test found no tendency for one station to yield larger or smaller measurements than any other station, except for gross beta results (based on a *p-value* of 0.0148); however, a post-hoc analysis of the Friedman test detected no differences among stations. Overall, these statistical tests do not appear to indicate differences in gross alpha/beta results, and concentrations of ^{238}U, ^{230}Th, and total alpha-emitting radium (including ^{226}Ra) among the five monitoring stations.

TABLE 6

SUMMARY OF STATISTICAL TEST EXAMINING AIRBORNE PARTICULATE RADIONUCLIDE RESULTS

Statistical Test	Result of Statistical Test				
	Gross Alpha	**Gross Beta**	**^{238}U**	**^{230}Th**	**Total Alpha-Emitting Radium**
Kruskal-Wallis[1]	No significant differences (p = 0.9191)	No significant differences (p = 0.9655)	No significant differences (p = 0.7513)	No significant differences (p = 0.3728)	No significant differences (p = 0.9168)
Friedman[2]	No station tended to have larger or smaller measurements than any other (p = 0.408)	Test resulted in a *p-value* of 0.0148, but a post-hoc analysis did not detect differences among the stations	No station tended to have larger or smaller measurements than any other (p = 0.7899)	No station tended to have larger or smaller measurements than any other (p = 0.2391)	No station tended to have larger or smaller measurements than any other (p = 0.5027)

Notes:

1 Results from the statistical software package R version 3.1.2 using the non-parametric Kruskal-Wallis test to compare the various radionuclide mean/median characteristics among the five monitoring stations. A p-value equal to or less than 0.05 suggests significant differences in mean/median characteristics among the stations. A p-value of greater than 0.05 suggests that the mean/median characteristics among the stations are comparable. See Appendix D to examine the Kruskal-Wallis test output from R.

2 Results from the statistical software package R version 3.1.2 using the non-parametric Friedman test to identify tendencies for measurements from one station to be larger or smaller than at any other station. A p-value equal to or greater than 0.05 suggests no tendency for one station to yield larger or smaller measurements than any other station. A p-value less than 0.05 suggests that one or more stations tended to yield measurements larger or smaller than other stations. See Appendix D to examine the test output from R.

4.1.8 Comparison of Gross Alpha to Radionuclide-Specific Results

The radionuclide-specific results examined in this section—^{238}U, ^{230}Th, and total alpha-emitting radium results—were compared to gross alpha results. Because each of these radionuclides (^{238}U, ^{230}Th, as well as ^{223}Ra, ^{224}Ra, and ^{226}Ra included in the total alpha-emitting radium result) is an alpha-emitting radionuclide, its concentration in a sample will be a component of (and not exceed) the gross (or total) alpha activity of the sample. To determine if the data conform to this relationship, the detected (non-U-coded) radionuclide-specific results were plotted against detected (non-U-coded) gross alpha results (see Exhibits 11-13). Each plot has a line representing a 1:1 ratio for the subject alpha-emitting radionuclide vs gross alpha (i.e., points on the line would indicate equal reported alpha-emitting radionuclide and gross alpha concentrations). Points above this line represent samples exhibiting a radionuclide-specific result that was less than its gross alpha result, indicating conforming data because the alpha-emitting radionuclide result was a component of, and did not exceed, the gross alpha result. Points below the 1:1 line represent a sample with an alpha-radionuclide result greater than its gross alpha result. This would not conform to the expectation that alpha-emitting radionuclide results would be less than gross alpha results (some nonconforming data may be expected when results are near the method detection limit).

EXHIBIT 11

URANIUM-238 AND GROSS ALPHA RESULTS

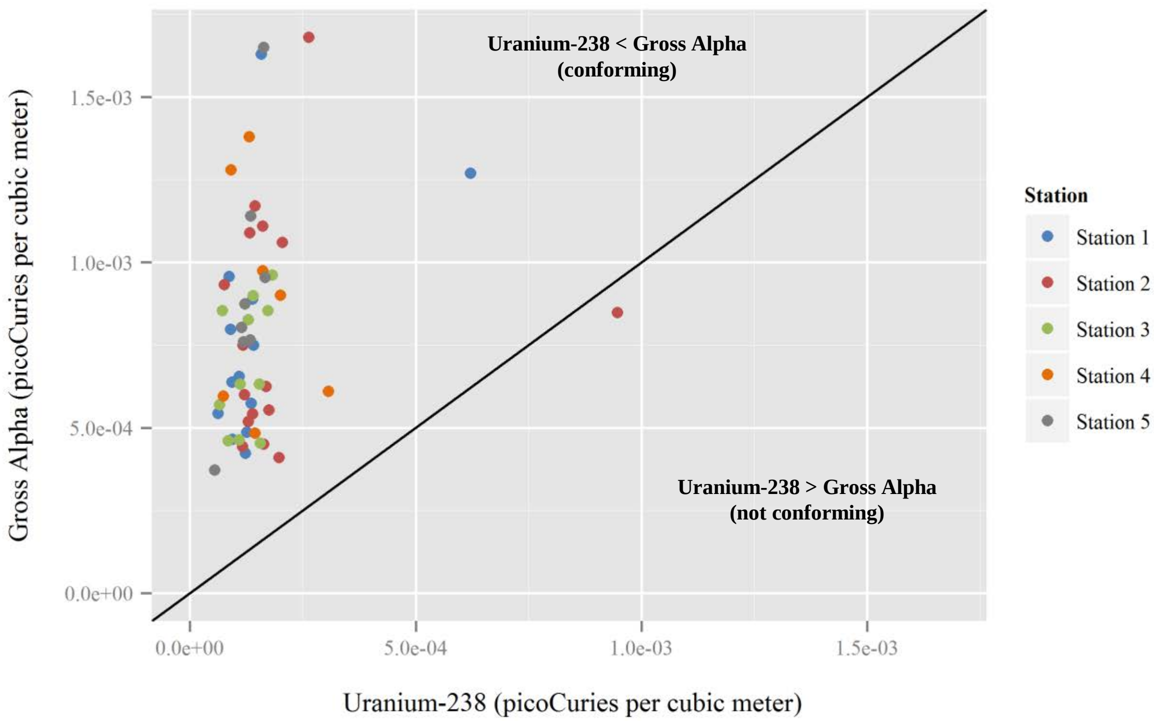


Exhibit 11 shows that all but one of the ^{238}U results conform to their corresponding gross alpha results. The one exception was the sample collected at Station 2 on May 22, 2014, which yielded a ^{238}U result of 9.47E-04 pCi/m^3 (notably the highest ^{238}U result among the data evaluated) and a gross alpha result of 8.48E-04 pCi/m^3.

EXHIBIT 12

THORIUM-230 AND GROSS ALPHA RESULTS

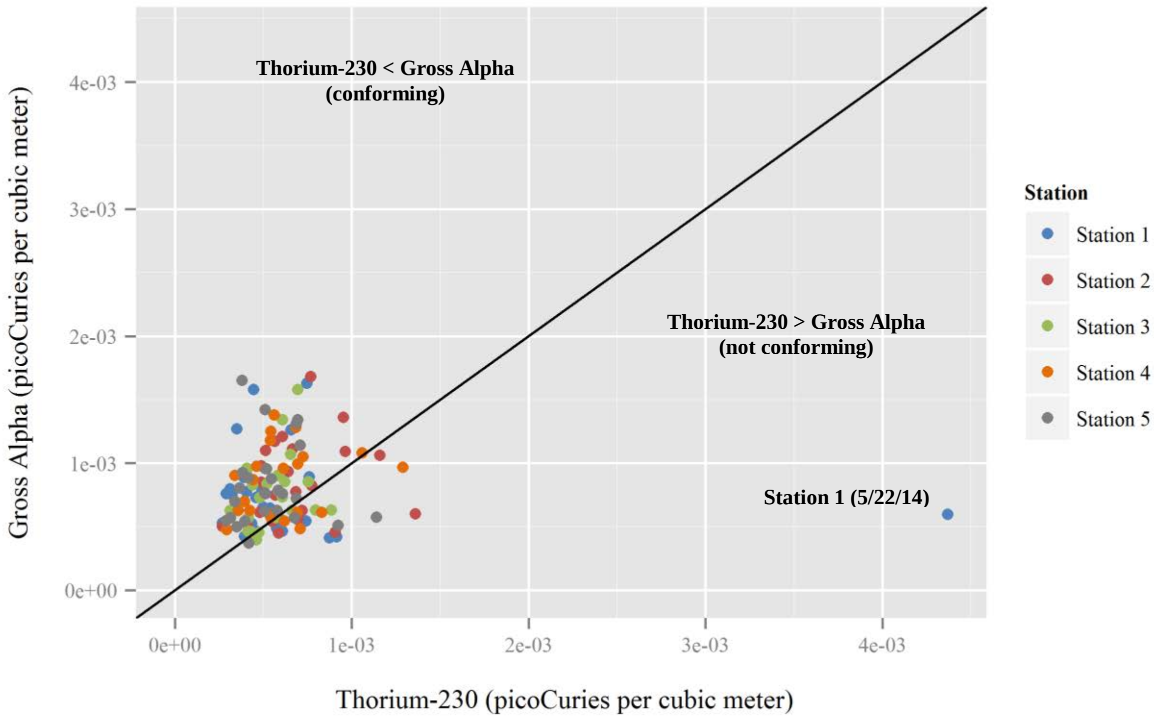


Exhibit 12 indicates numerous ^{230}Th results that do not conform to the corresponding gross alpha results. Many of these occurrences possibly relate to nearness of results to the laboratory detection capability (note that all results but one are in a cluster spanning the low end of the 1:1 line). The highest ^{230}Th result of 4.37E-03 pCi/m^3 (from the sample collected at Station 1 on May 22, 2014) notably does not conform to its corresponding gross alpha result of 5.95E-04 pCi/m^3. This observation prompts some speculation regarding its representativeness of actual ^{230}Th concentrations.

EXHIBIT 13

TOTAL ALPHA-EMITTING RADIUM AND GROSS ALPHA RESULTS

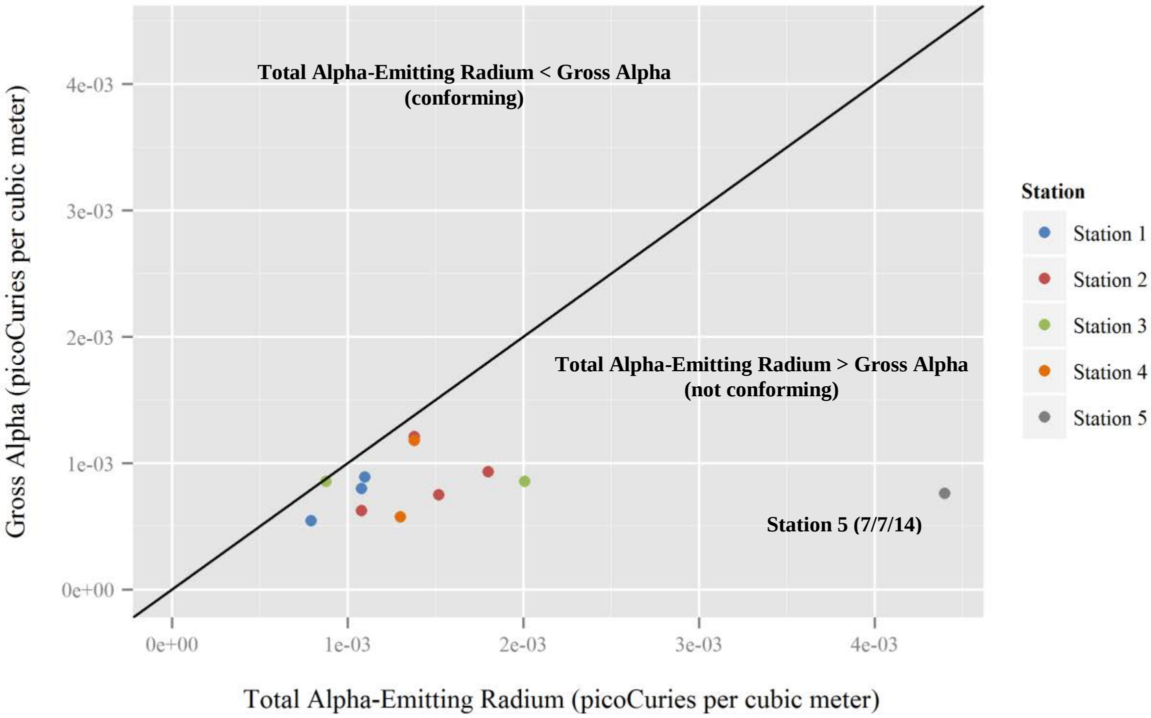


Exhibit 13 shows that most of the detected total-alpha emitting radium results do not conform to their corresponding gross alpha result. Many of these occurrences possibly relate to nearness of results to the laboratory detection capability, but as observed with the ^{238}U and ^{230}Th data, the highest total alpha-emitting radium result of 4.40E-03 pCi/m^3 (from the sample collected at Station 5 on July 7, 2014) notably does not conform to its corresponding gross alpha result of 7.59E-04 pCi/m^3. Likewise, this observation prompts some speculation that this maximum total alpha-emitting radium result is possibly unrepresentative.

Overall, a comparison of specific alpha-emitting radionuclide results (^{238}U, ^{230}Th, and total alpha-emitting radium results) to their corresponding gross alpha results indicated occasions of nonconformance of the radionuclide-specific result to its gross alpha result (because the radionuclide-specific result exceeded its corresponding gross alpha result). Data users should be aware of this characteristic in the data.

4.2 RADON MONITORING

Radon (^{222}Rn) has been identified as a radiological parameter of interest because it is a decay product of ^{226}Ra, a radionuclide of concern at WLLS. ^{222}Rn is also generated by decay of ^{226}Ra naturally occurring in soil and rock, and a significant portion of this ^{222}Rn is naturally released from the ground into the atmosphere because, as a noble gas, radon becomes unbound to soil and rock. The rate of release from the ground and concentration of ^{222}Rn in outdoor air depend on a number of factors including local geology, soil porosity, soil moisture, and atmospheric pressure. Outdoor ^{222}Rn levels fluctuate but are normally around 0.4 pCi/L of air (EPA 2012).

4.2.1 Sampling Procedure

Electret ion chamber radon detectors (Rad Elec E-PERM®) equipped with high-volume chamber ("H-chamber") short-term ("ST") electrets were used to assess ^{222}Rn levels at each off-site monitoring station. Electret measurements proceed by use of an Electret Voltage Reader to measure a beginning and final electrical charge on the electret exposed for a specified time period. In addition, one pocket ion chamber per station (co-located with the electret ion chamber radon detectors) provides a gross gamma activity measurement used in the final ^{222}Rn measurement calculation (see Appendix C to examine this calculation). Electrets and pocket ion chambers are read weekly to yield a ^{222}Rn measurement that has been continuously integrated (averaged) over the week-long exposure duration. Three electret ion chambers are deployed per off-site monitoring station to provide redundant measurements in case of a device failure, and to provide an indication of total method precision.

4.2.2 Data Validation, Verification, and Usability

^{222}Rn measurements were reviewed by the START project manager and were qualified as necessary based on sampling deviations noted in the field or any irregularities in the data. Qualifiers assigned to the radon measurements included the following:

<u>Off-Scale Pocket Ion Chamber Readings (G1)</u>

Several pocket ion chamber exposure readings exceeded the 2.0 milliroentgen (mR) scale of the pocket ion chamber; for these measurements, a final exposure reading of 2.0 mR (the maximum scale reading) was assumed, possibly resulting in a low bias to the gamma exposure value input to the calculation of ^{222}Rn concentration. Because higher gamma exposure values induce larger subtractions to the final ^{222}Rn concentration, ^{222}Rn concentrations associated with off-scale pocket ion chamber readings (those flagged "G1") may be biased high.

Electret Measurements Below Usable Voltage (LV1, LV2, and LV3)

Per the manufacturer, an electret showing a reading of less than 200 volts should not be used for measurements because the weaker electrostatic field is not as consistent in collecting the ions efficiently. Some replicate measurements were associated with a final reading below 200 volts; these readings were not used in calculation of the weekly station ^{222}Rn measurement. Weekly station measurements associated with electret readings below 200 volts were flagged either "LV1" (one replicate was below 200 volts), "LV2" (two of the three replicate electrets fell below 200 volts), or "LV3" (each of the three replicates fell below 200 volts). Only one weekly ^{222}Rn measurement was flagged "LV3" (the measurement at Station 4 from June 20-27); because each of the three replicate measurements was unusable, no ^{222}Rn concentration was reported. Starting on October 21, 2014, the corrective action of removing from service any electret with a reading of less than 300 volts was taken to decrease occurrences of final electret readings below 200 volts.

Missing Measurements (V1, V2, and E)

Vandalism affected ^{222}Rn measurements at Station 4 during weeks ending July 3 and 11, 2014 (see Appendix B, Table B-6 for explanations of qualifiers "V1" and "V2"). Several measurements were associated with one or more replicate electret readings yielding a negative ^{222}Rn concentration; these values were not included in the weekly calculated ^{222}Rn concentration for the station, and are flagged as "E1," "E2,", or "E3" indicating the number of negative replicate measurements (no mean ^{222}Rn concentration is reported for measurements flagged "E3").

Replicate Measurements Identified as Outliers by Statistical Evaluation (OH and OL)

Following determination of data usability with respect to the aforementioned qualifiers, an assessment for low and high outliers was conducted where three usable replicate measurements remained (a minimum of three measurements is required to statistically assess for outliers). Dixon's statistical procedure for outlier identification was used to assess for outliers; this procedure was implemented as described in *U.S. Nuclear Regulatory Commission NUREG 1475*, Chapter 26.4, assuming a probability of erroneously labeling an observation as an outlier (α) of 0.05. Use of Dixon's procedure was also recommended by Rad Elec, Inc., the manufacturer of the radon detectors used at WLLS, to identify any suspect measurements. Where an outlier was detected, it was not reflected in the reported weekly station ^{222}Rn concentration (the replicate ^{222}Rn concentrations are listed in Appendix C, Table C-1). The qualifiers "OH" and "OL" indicate that one of the three replicate ^{222}Rn measurements was identified either as high (OH) or low (OL), and was not used to calculate the reported mean weekly station ^{222}Rn concentration.

Some weekly measurements could not be assessed for identification of outliers using Dixon's procedure because fewer than three replicate measurements were available. Data users should be aware that because these weekly station measurements were not amenable to this procedure, they may be less robust than measurements amenable to Dixon's procedure that led to removal of detected outliers from the reported average result. Measurements flagged "LV1," "LV2," "E1," and "E2" are affected because these derived from fewer than three usable replicate measurements; these measurements are regarded as not meeting data quality objectives (DQO), and are depicted as open circles in the radon time series plot on Exhibit 14 and are not included in the boxplot on Exhibit 15.

4.2.3 Radon Results and Evaluation

The following describes ^{222}Rn results from weekly monitoring from April 25 through February 17, 2015.

Summary Statistics

For each monitoring station, Table 7 lists minimum, median, and maximum ^{222}Rn concentrations.

TABLE 7

SUMMARY STATISTICS OF RADON-222 RESULTS

Summary Statistic	Station 1	Station 2	Station 3	Station 4	Station 5 (reference)
Number of Measurements	43	43	43	41	42
Minimum Concentration	0.19	0.15	0.12	0.09	0.11
Median Concentration	0.28	0.24	0.27	0.21	0.30
Maximum Concentration	1.01	1.81 LV2	1.88 LV1	0.95 E1	1.45 LV1

Notes:

All concentrations in picoCuries per liter (pCi/L)

E Indicates one of three replicate measurements yielded a negative radon concentration. The negative radon value was not included in the reported mean radon concentration.

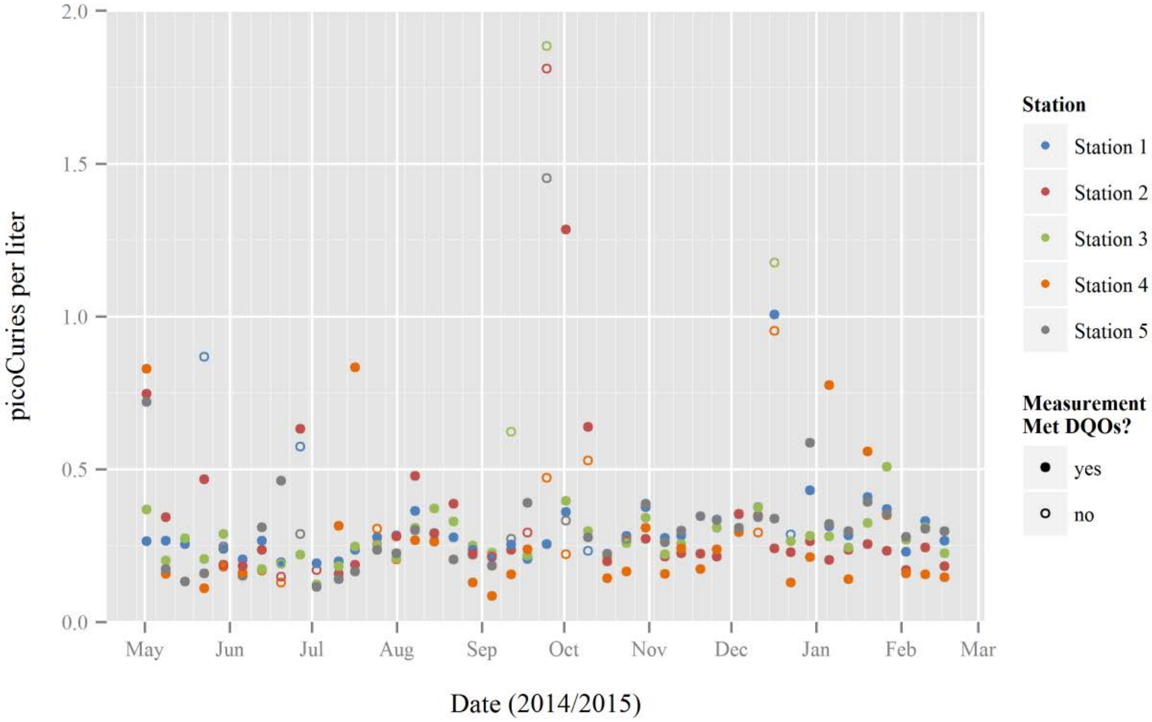
LV Indicates one (LV1) or two (LV2) of the three replicate measurements were not used in the calculation of the reported mean ^{222}Rn concentration because the measurement derived from an electret showing a reading below 200 volts.

Time Series Plot

The only discernable trend or pattern shown on the Exhibit 14 time series plot of ^{222}Rn results is that radon concentrations measured over the same week often appear related by a common component that varies in a sinusoidal pattern.

EXHIBIT 14

TIME SERIES PLOT OF RADON-222

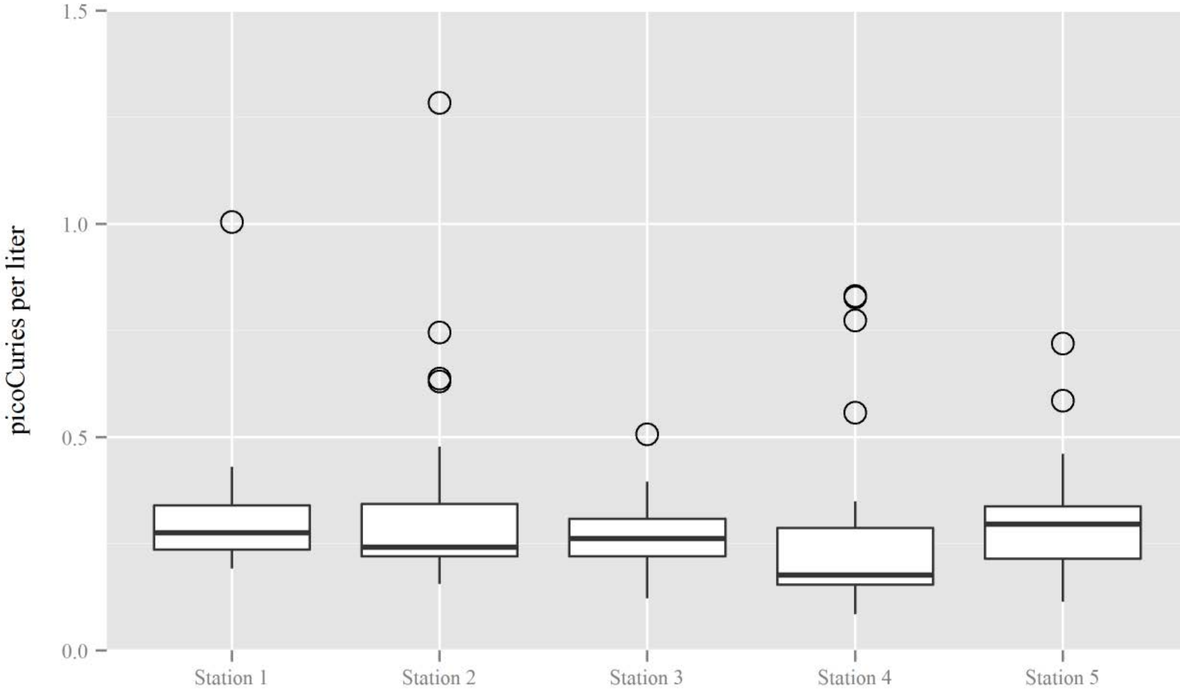


Box Plots

Examination of the ^{222}Rn box plots in Exhibit 15 suggests that the median of ^{222}Rn concentrations is similar among the five monitoring stations. The box plots suggest upper end outlier concentrations (indicated by open circles) at each of the five stations (including the reference Station 5), about which data users should be aware; however and notably, maximum ^{222}Rn concentrations detected at each of the five stations are within an order of magnitude.

EXHIBIT 15

BOX PLOTS OF RADON ACTIVITY



4.2.4 Statistical Analyses

The Kruskal-Wallis and Friedman tests were used to evaluate the ^{222}Rn data, as these were applied to evaluate the airborne particulate radionuclide data (see Section 4.1.8). Statistical software package R was used to apply the Kruskal-Wallis and Friedman tests (see Appendix D for the input data sets, R scripts, and R output). Radon measurements not meeting DQOs (those flagged "LV1," "LV2," "E1," and "E2"—see Section 4.2.2) were not included in the statistical analyses.

The Kruskal-Wallis and Friedman test found a tendency for some station ^{222}Rn measurements to be larger or smaller than measurements at other stations; however, none of the perimeter stations (Stations 1– 4) showed a tendency to yield larger or smaller measurements than the reference station (Station 5). Table 8 summarizes the Kruskal-Wallis and Friedman test results.

TABLE 8

SUMMARY OF STATISTICAL TEST EXAMINING RADON-222 RESULTS

Statistical Test	Result of Statistical Test for Radon-222
Kruskal-Wallis[1]	Station 4 tended to yield smaller measurements than Station 1; however, none of the perimeter stations (Stations 1 – 4) showed a tendency to yield larger or smaller measurements than the reference station (Station 5) (p = 0.00851)
Friedman[2]	Station 2 tended to have smaller measurements than Station 1 and Station 4 tended to yield smaller measurements than Stations 1 and 3; however, none of the perimeter stations (Stations 1-4) showed a tendency to yield larger or smaller measurements than the reference station (Station 5). (p = 0.0002538)

Notes:

1 Results from the statistical software package R version 3.1.2 using the non-parametric Kruskal-Wallis test to compare the various radionuclide mean/median characteristics among the five monitoring stations. A p-value equal to or less than 0.05 suggests significant differences in mean/median characteristics among the stations. A p-value of greater than 0.05 suggests that the mean/median characteristics among the stations are comparable. See Appendix D to examine the Kruskal-Wallis test output from R.

2 Results from the statistical software package R version 3.1.2 using the non-parametric Friedman test to identify tendencies for measurements at one station to be larger or smaller than at any other station. A p-value equal to or greater than 0.05 suggests no tendency for one station to yield larger or smaller measurements than any other station. A p-value less than 0.05 suggests that one or more stations tended to yield measurements larger or smaller than other stations. See Appendix D to examine the test output from R.

4.3 EXPOSURE RATE MEASUREMENTS

The following sections discuss continuous external gamma exposure rate measurements taken at the five monitoring stations by use of Saphymo GammaTRACERs. Although a release of RIM via airborne particulates from WLLS is not anticipated to result in an off-site external gamma exposure rate distinguishable from background variability, acquisition of these data continues because the data possibly will be used as a reference for future monitoring campaigns that include exposure rate measurements. Moreover, sources of gamma activity not related to West Lake Landfill RIM may occasionally induce a detector response above background. Such sources may include nuclear medical materials passing by the detector (including patients receiving nuclear medicine), cosmic events (such as naturally occurring gamma-ray bursts), or precipitation to which naturally occurring airborne radionuclides adhere (as indicated in measurements presented herein and discussed in Section 4.3.2).

4.3.1 Monitoring Procedure

At each of the five monitoring stations, EPA has installed a Saphymo GammaTRACER exposure rate monitor that incorporates two Geiger-Mueller (GM) detector tubes (a high-range detector and a low-range detector). The GM tubes respond to ionization produced within the detector by gamma radiation. On an hourly basis, the GammaTRACER is programmed to report an average exposure rate reading from the previous hour-long interval. The exposure rate measurement is reported in units of microRoentgens per hour (μR/hr). The hourly measurements are transmitted wirelessly to a field command post computer and then logged by EPA Environmental Response Team's Viper data management software. Typical exposure rate readings in outdoor environments fluctuate around 10 μR/hr—this background radiation is primarily the result of cosmic and terrestrial sources of radiation (NCRP 1987).

4.3.2 Data Validation, Verification, and Usability

The exposure rate data undergo review by a member of the EPA Environmental Response Team knowledgeable of the Saphymo GammaTRACER system, and by START field staff aware of day-to-day field activities. These reviews have revealed the following information regarding the data about which users should be aware:

- At Station 1, exposure rate readings dropped by approximately 2 to 3 μR/hr on August 22, 2014. This shift in the exposure rate readings was investigated and found to have been caused by an approximately 1-foot layer of crushed limestone gravel that had been placed on the ground surface beneath the Station 1 GammaTRACER. The gravel had been placed in preparation for construction of a training structure for the Robertson Fire Protection District adjacent to firehouse #2. The gravel had evidently caused measurable shielding of naturally occurring terrestrial radiation. The lower exposure rate readings continued until September 30, 2014, when the Station 1 GammaTRACER had to be moved to make way for the construction (the GammaTRACER was moved approximately 370 feet to the north-northeast closer to the firehouse #2 building). As evident in the plot of exposure rate readings for Station 1 (see Appendix E, Exhibit E-1), exposure rate readings increased 2 to 3 μR/hr after movement of the GammaTRACER to the new location.

- At Station 5, the wireless data transmission from the Station 5 GammaTRACER to the Saphymo receiver at the field office was initially unreliable, and some May 2014 measurements from Station 5 were intermittently lost. The unreliable data connection had been remedied by May 28, 2014.

- Plots of the GammaTRACER data revealed numerous temporary spikes in the exposure rate readings at each of the stations that occurred simultaneously at the five stations. Plotting the GammaTRACER data against precipitation events revealed a strong correlation (see Exhibit 16), indicating that the temporary spikes in exposure rate readings likely had resulted from "precipitation scavenging" (or washout) of airborne radionuclides. In this process, radionuclides (primarily radon daughter products) suspended as aerosols in the atmosphere coalesce with precipitation and are transported with the falling precipitation to the ground surface. These precipitation-scavenged radionuclides can then cause an increase in exposure rates measured in air near the ground surface (Paatero and Hatakka 1999).

Overall, the Saphymo GammaTRACER measurements are usable for the intended purpose of providing pre-construction baseline exposure rate data.

4.3.3 GammaTRACER Monitoring Data and Evaluation

Exhibit 16 shows a time series plot of GammaTRACER data acquired at the five stations from May 1, 2014 to January 16, 2015. Also on this plot, precipitation events are indicated by vertical bands. These events were identified by use of data obtained from the National Oceanic and Atmospheric Administration (NOAA) Quality Controlled Local Climatological Data (QCLCD) dataset (NOAA 2015)—specifically precipitation data acquired at the Lambert-St. Louis International Airport Station 13994, approximately 2 miles east of WLLS. A vertical band indicates a recorded hourly precipitation of 0.01 inch or more (events of only trace precipitation are not represented on Exhibit 16). Thicker bands indicate a precipitation event persisting over multiple hours. Time series plots of individual station data are in Appendix E.

EXHIBIT 16

TIME SERIES PLOT OF EXPOSURE RATE BY SAPHYMO GAMMATRACERS

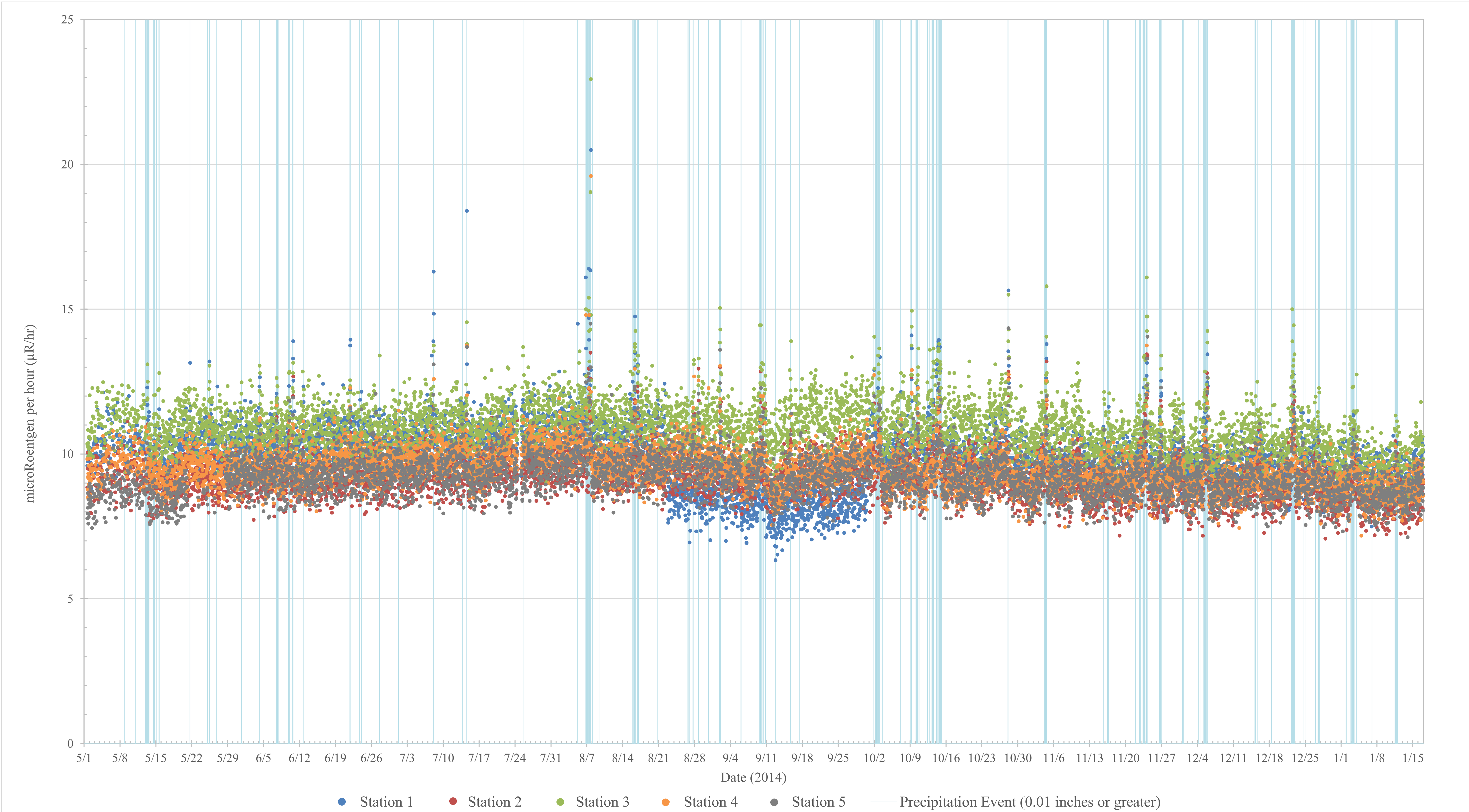


Exhibit 16 illustrates the following characteristics of the GammaTRACER data:

- Exposure rates are around 10 μR/hr—a typical exposure rate within outdoor environments (NCRP 1987)—with rates at some stations tending to be slightly higher or lower than 10 μR/hr (an expected outcome due to variations in local geology and surface conditions).
- At Station 1, exposure rate readings were noticeably lower between August 22 and September 30, 2014. As discussed in Section 4.3.2, this was the time period when crushed limestone gravel was beneath the detector (related to a nearby construction project). Exposure rate readings increased when the detector was moved to a new location to make way for construction.
- Numerous temporary spikes in the exposure rate readings strongly correspond to precipitation events. As discussed in Section 4.3.2, these occurrences likely resulted from precipitation scavenging of naturally occurring airborne radionuclides (likely radon daughter products) that caused a temporary increase in near ground-level exposure rates. Notably, all measurements exceeding 15 μR/hr appear to be associated with a precipitation event.

Overall, the gamma rate measurements appear typical for an outdoor environment.

4.3.4 Statistical Analysis

Statistical analysis to compare the mean/median characteristics among stations was not conducted because differences in the mean/median characteristics among the five stations are already evident on plots of the data (e.g., Stations 1, 2, 4, and 5 tend to have lower exposure rate measurements than Station 3). These differences are anticipated because localized differences in geology and ground surface conditions measurably affect exposure rates (e.g., placement of crushed limestone gravel beneath the Station 1 GammaTRACER detector noticeably lowered the exposure rate).

4.4 ENVIRONMENTAL DOSIMETRY

Landauer, Inc. InLight optically stimulated luminescent dosimeters (OSLs) are deployed at each station to passively measure external exposure, supplementing the exposure rate measurements obtained from the Saphymo GammaTRACERs (see Section 4.3). The InLight OSLs, deployed for approximately 30 days, provide long-term dose measurements. The InLight OSLs have a nominal minimum detectable dose of 0.1 millirem (mrem) (detecting x-ray and gamma photons with energies exceeding 15 kiloelectron-volts [keV]), and measurements are reported as an ambient dose equivalent. (Although the OSLs are deployed primarily to measure external gamma activity, the OSLs are also sensitive to beta radiation with energies exceeding 500 keV at a minimum detectable dose of 20 mrem.)

Consistent with discussion regarding the Saphymo GammaTRACER exposure rate measurements (Section 4.3), a release of RIM via airborne particulates from WLLS is not anticipated to induce an off-site external exposure that would be measureable by use of OSLs; however, the data are acquired for possible use as a reference for future monitoring campaigns that include dosimeter measurements.

4.4.1 Monitoring Procedure

Landauer, Inc. InLight OSLs are deployed at each station for continuous periods of approximately 30 days. Three OSLs are deployed per station to provide replicate measurements. When the 30-day deployment period ends, the OSLs are retrieved and shipped to the dosimeter provider for analysis.

4.4.2 Data Validation, Verification, and Usability

Review of the OSL data and field observations have revealed the following information regarding the data about which users should be aware:

- After reception of the first two rounds of OSL readings, it was suspected that elevated gamma activity from nearby masonry walls may have been contributing to OSL dose readings at some stations. This was confirmed in June 2014, when EPA and START, using a Ludlum microR, detected higher dose readings near the masonry walls at Stations 2, 3, and 4 near where the OSLs had been deployed (it is not uncommon for buildings constructed of stone or bricks to have higher natural radiation levels than buildings made of other materials such as wood [Nuclear Regulatory Commission [NRC] 2011]). Based on this information, the OSLs were re-positioned away from masonry walls (the OSLs at each station were re-positioned next to that station's GammaTRACER detector). The OSLs at Stations 1, 2, 3, and 5 were re-positioned on July 1, 2014. The OSLs at Station 4 were re-positioned on October 31, 2014.

- The dosimeter provider reports a gross dose in units of mrem for each OSL badge. The gross dose includes the dose received during the 30-day deployment, but also includes ambient dose received during the pre- and post-deployment periods because the element in the OSL is continuously exposed to ambient gamma radiation (pre-deployment time being the duration beginning when the badge is prepared by the provider and ending when the badge is deployed by the user; post-deployment being the duration beginning when the badge is retrieved by the user and ending when the badge is read by the provider). Thus, for a badge deployed 30 days, a significant portion of the gross dose reported is likely to be from doses received during pre- and post-deployment periods. Because of this, net dose values—calculated by determining differences in gross dose measurements among OSL badges—may be more useful depending on intended use of the data.

Overall, the OSL environmental dosimetry measurements are usable for measuring relative differences in long-term dose rates among the stations; however, data users should be aware that, as stated above, the OSL badges receive doses during pre- and post-deployment periods (e.g., dose received during shipment), resulting in dose readings that vary among the measurements during a particular deployment. Moreover, data users should be aware that a release of RIM via airborne particulates from WLLS is not anticipated to induce an off-site external exposure that would be measureable by use of OSLs.

4.4.3 Environmental Dosimeter Results and Evaluation

Table 9 lists the monthly OSL environmental dosimeter results for May 2014 through January 2015.

TABLE 9

ENVIRONMENTAL DOSIMETER RESULTS – GROSS DOSE

Deployment Period (2014)	Days Deployed	Station 1	Station 2	Station 3	Station 4	Station 5 (background)
April 29 – May 30	31	9.8	12.9	9.9	10.9	9.2
May 30 – July 1	32	15.0	17.4	15.3	15.9	13.9
July 1 – August 2	31	11.8	10.9	11.5	12.4	10.9
August 2 – September 2	32	10.8	10.8	10.9	11.9	10.6
September 2 – October 3	31	8.8	10.0	10.2	11.4	10.1
October 3 – October 31	28	11.9	10.9	11.4	12.5	11.5
October 31 – December 2	32	11.0	10.6	11.0	11.0	11.0
December 2 – January 7	30	11.6	11.5	12.0	11.8	11.4
January 7 – February 6	30	9.8	9.5	9.9	10.4	9.2

Notes:

All units in millirem (mrem)

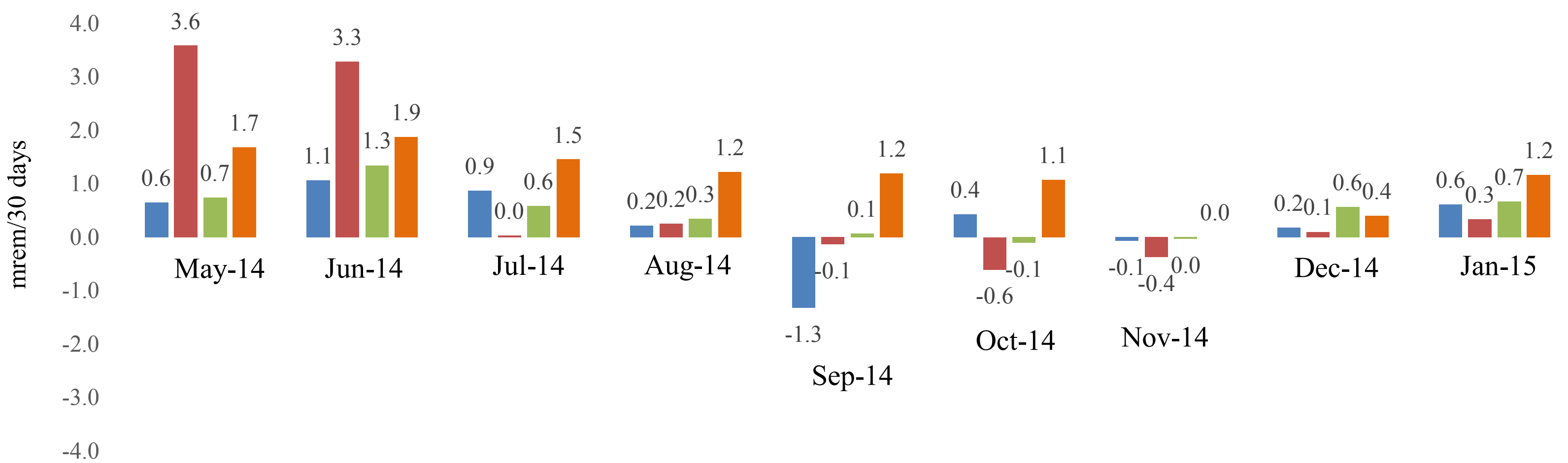
Typical outdoor environmental dosimetry readings range from 5 to 15 mrem per month (see NCRP 1987, Table 5.4); however, as previously described, OSL dosimeter results include contributions to dose received during pre- and post-deployment periods.

Exhibit 17 shows the Station 1 through 4 OSL environmental dosimetry results net of the Station 5 (the reference station) OSL result. Relative differences between OSL results were notably greater before the OSLs were moved away from masonry building walls (on July 1 for Stations 1, 2, 3, and 5, and October 31 for Station 4). Also shown on Exhibit 17 is the difference between the minimum and maximum result (or span) for each deployment period. These values can be compared to the span between the reported 5th and 95th percentile values of the terrestrial component of the outdoor gamma-ray effective dose in the conterminous 48 states derived from airborne radiation measurements by the National Uranium Resource Evaluation (NURE) programs of 3.3 mrem/month (NCRP 2009).

EXHIBIT 17

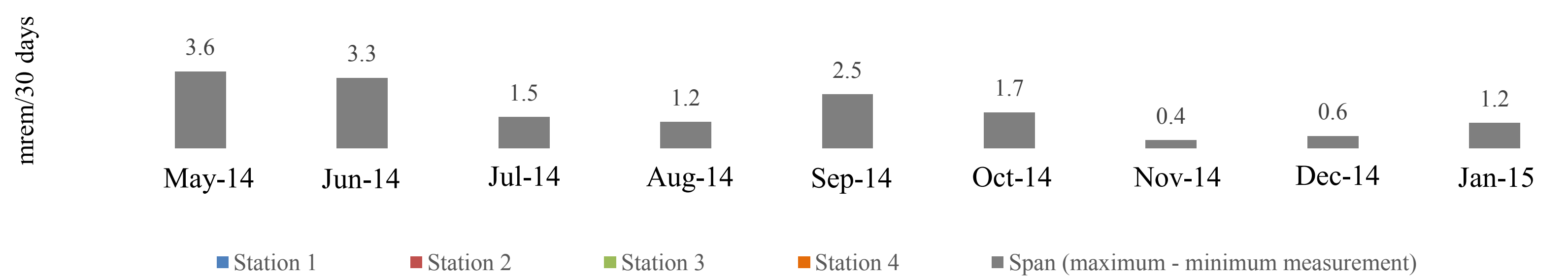
ENVIRONMENTAL DOSIMETRY RATES BY OSL DOSIMETERS

Environmental Dosimetry Rates Net of Background (Station 5)



Span of Environmental Dosimetry Dose Rates Among Stations 1 - 5

These span values can be compared to the span between the 5th and 95th percentile value of the terrestrial component of the outdoor gamma-ray effective dose in the conterminous 48 states derived from airbone radiation measurements by the NURE programs of 3.3 mrem/month.



Overall, the OSL dosimetry data appear normal for outdoor ambient measurements, considering the likely contributions to the dose readings from masonry building walls that occurred before the OSLs were re-positioned away from building walls.

4.4.4 Statistical Analysis

Statistical analysis to compare the mean/median characteristics among stations was not conducted because differences in the mean/median characteristics among the five stations is anticipated (as with the GammaTRACER exposure rate data)—localized differences in geology and ground surface conditions measurably affect exposure rates.

5.0 SUMMARY OF OBSERVATIONS

The following summarizes interim observations regarding radiological data acquired from approximately April to January-February 2015 at off-site monitoring stations:

Radionuclides on Airborne Particulates

To determine airborne concentrations of radionuclides transported via airborne particulates, airborne particulates are being collected onto glass fiber filter media by use of high-volume air samplers. Air sampling occurs continuously, and air filter samples are collected every 7 days and submitted for laboratory analysis for gross alpha, gross beta, gamma-emitting radionuclides, isotopic uranium, isotopic thorium, and total alpha-emitting radium. The air filter results evaluated were gross alpha/beta, ^{238}U, ^{230}Th, and total alpha-emitting radium (including ^{226}Ra). Examination of box plots indicated similarity of medians and distributions of these parameters among the five monitoring stations. The box plots did reveal some suggested outliers about which data users should be aware, but the outliers were within an order of magnitude of the maximum concentrations detected among the other stations.

Two statistics tests—the Kruskal-Wallis and Friedman tests—were used to test for differences in gross alpha/beta, ^{238}U, ^{230}Th, and total alpha-emitting radium (including ^{226}Ra) concentrations among the five monitoring stations. The Kruskal-Wallis test did not identify significant differences in the mean/median characteristics among the five monitoring stations based on the data examined (gross alpha/beta, ^{238}U, ^{230}Th, and total alpha-emitting radium), and the Friedman test found no tendency for one station to yield larger or smaller measurements than any other station.

A comparison of specific alpha-emitting radionuclide results (^{238}U, ^{230}Th, and total alpha-emitting radium results) to their corresponding gross alpha results occurred to determine if the data conformed to expectation that alpha-emitting radionuclide results would be a component of (and thus less than) gross alpha results. This evaluation revealed numerous instances of nonconformity of the data to this expectation. Notably, the maximum detected ^{238}U, ^{230}Th, and total alpha-emitting radium concentrations did not conform to corresponding gross alpha concentrations. Data users should be aware of this characteristic of the data.

Radon

^{222}Rn has been identified as a radiological parameter of interest because it is a decay product of ^{226}Ra, a radionuclide of concern at WLLS. ^{222}Rn is also generated by decay of ^{226}Ra naturally occurring in soil and rock, and a significant portion of this ^{222}Rn is naturally released from the ground into the atmosphere because, as a noble gas, radon becomes unbound to soil and rock. Average weekly ^{222}Rn concentrations are measured at the five off-monitoring stations by use of electret ion chamber radon detectors (RadElec E-PERM®).

Examination of the radon box plots appears to show similar median radon concentrations among the five monitoring stations (although statistical testing suggested that Stations 2 and 4 tended to yield smaller radon measurements than other stations). The box plots suggest upper end outlier concentrations (indicated by open circles) at each of the five stations (including the reference Station 5) about which data users should be aware; however and notably, maximum detected radon concentrations among the five stations are within an order of magnitude (the station maximums range from 1.01 to 1.88 pCi/L).

Data users should be aware that about one in every three of the weekly radon measurements was qualified; these qualifications were primarily because either (1) one or more replicate measurements was deemed not usable because the final voltage reading was not within the manufacturer's recommended range for a reliable measurement, or (2) Dixon's statistical procedure detected an outlier among three usable replicate measurements.

Exposure Rate Measurements

Hourly exposure rate measurements are obtained by use of Saphymo GammaTRACER exposure rate monitors installed at each of the five off-site monitoring stations. Although a release of RIM via airborne particulates from the WLLS is not anticipated to induce an off-site external gamma exposure rate that would be distinguishable from background variability, the data are acquired for possible use as a reference for future monitoring campaigns that include exposure rate measurements. Review of the GammaTRACER data revealed that exposure rates at the five monitoring stations fluctuated around 10 μR/hr—a typical exposure rate for outdoor environments (NCRP 1987)—with readings at some stations tending to be slightly higher or lower than 10 μR/hr (expected due to variations in local geology and surface conditions). Numerous temporary spikes in the exposure rate readings corresponded to precipitation events, indicating likely precipitation scavenging (or washout) of airborne radionuclides (a process whereby radionuclides—primarily radon daughter products—suspended as aerosols in the atmosphere coalesce with precipitation and are transported with the falling precipitation to the ground surface). Overall, the gamma rate measurements appear typical for an outdoor environment.

Environmental Dosimetry

Month-long environmental dosimetry measurements are obtained at the off-site monitoring stations by use of Landauer, Inc. InLight OSLs to supplement exposure rate measurements obtained by use of Saphymo GammaTRACERs. The OSL dosimetry data appear normal for outdoor ambient measurements.

6.0 REFERENCES

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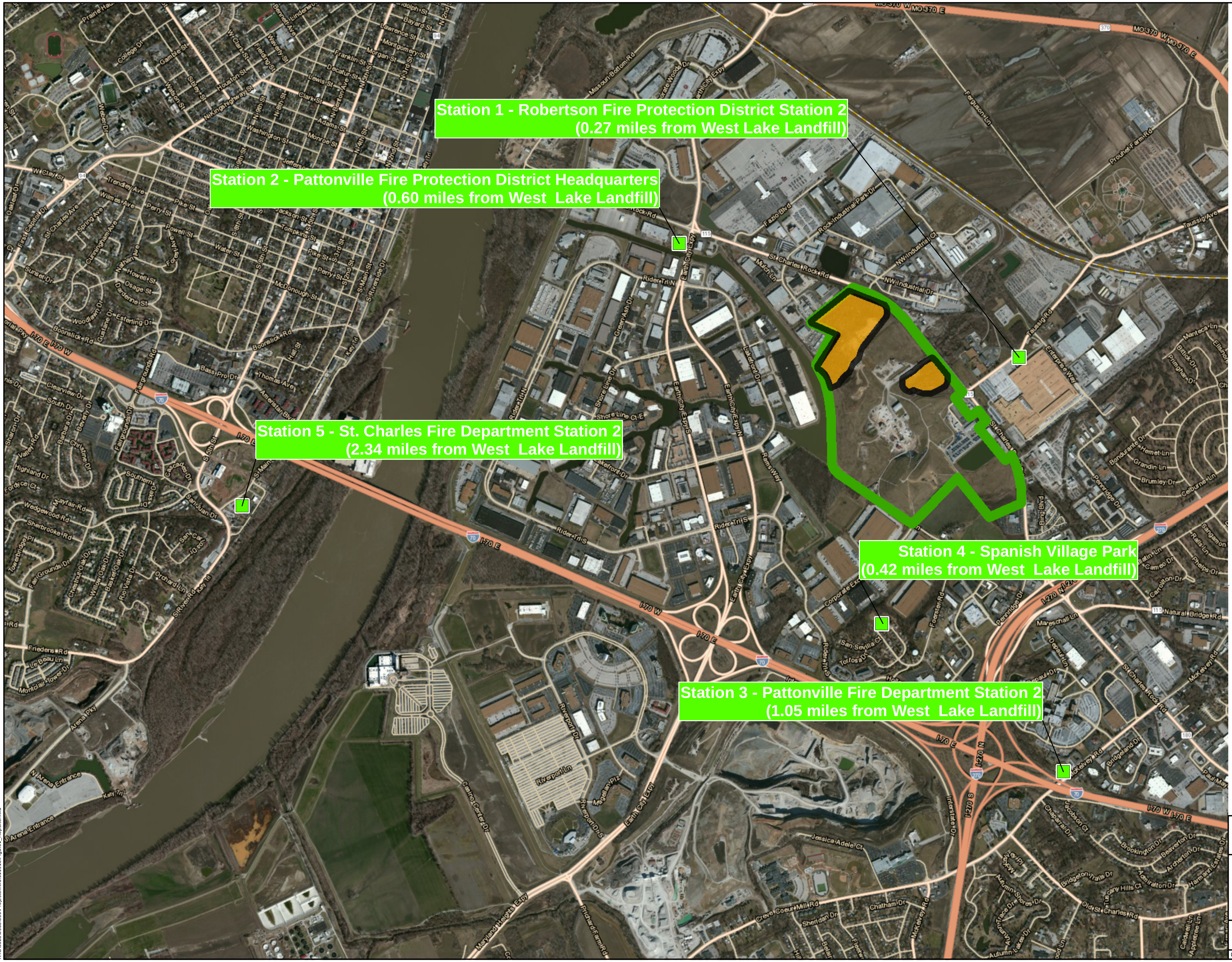
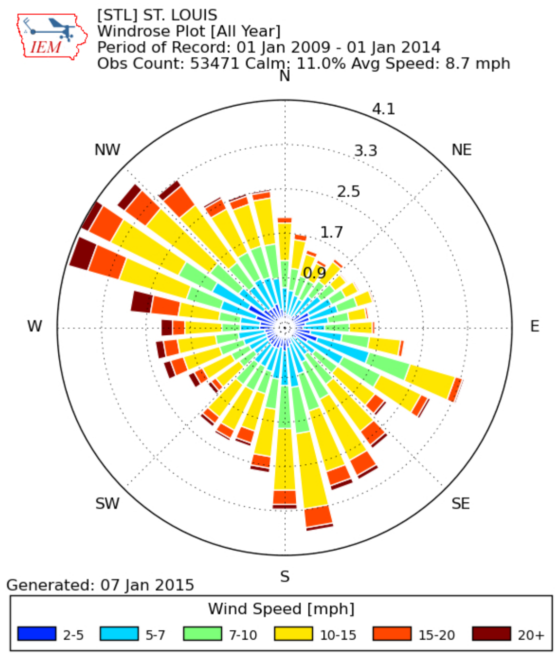
APPENDIX A

FIGURES



Legend

- Off-site air monitoring station
- West Lake Landfill Site Operable Unit 1 (radiological area)
- Bridgeton Landfill



N

0 1,000 2,000

Feet

Source: ArcGIS Online Aerial Imagery, 2013; Iowa State University of Science and Technology, 2015

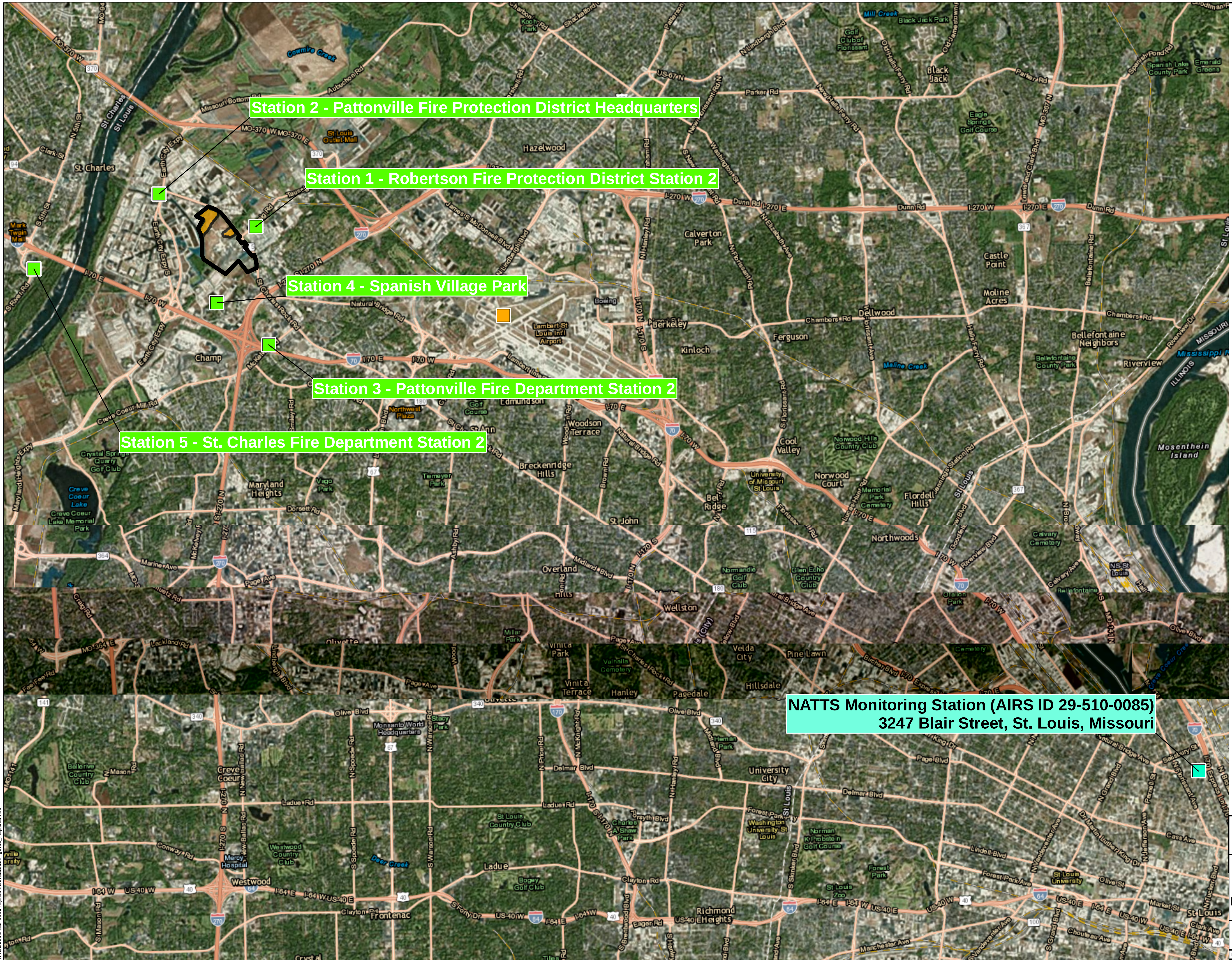
West Lake Landfill
Bridgeton, Missouri

Figure 1

Off-Site Air Monitoring Stations

TETRA TECH

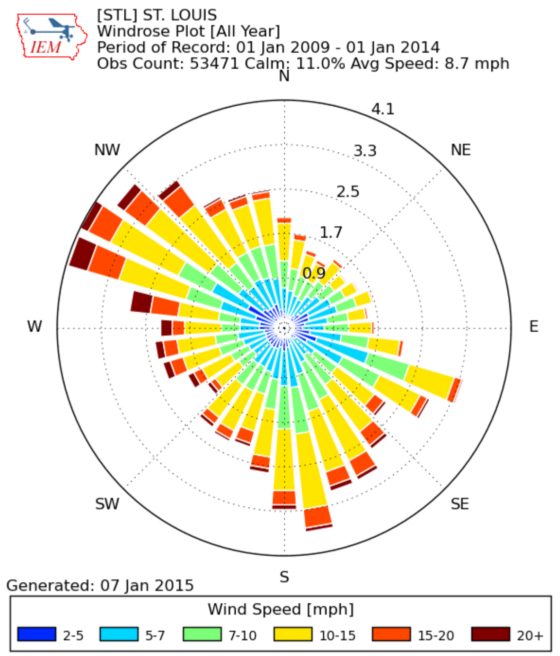
Date: 1/19/2015 Drawn By: Bill Spiking Project No: X9025.14.0058.000



Legend

- Lambert St. Louis International Airport Metar Station
- NATTS monitoring station
- Off-site air monitoring station
- Bridgeton Landfill
- West Lake Landfill Site Operable Unit 1 (radiological area)

NATTS National Air Toxics Trends Station



N

0 3,500 7,000

Feet

Source: ArcGIS Online Aerial Imagery, 2013; Iowa State University of Science and Technology, 2015

West Lake Landfill
Bridgeton, Missouri

Figure 2

Location of St. Louis NATTS Air Monitoring Station

TETRA TECH

Date: 1/19/2015 Drawn By: Gustavo Orozco Project No: X9025.14.0058.000

APPENDIX B

TABULATED AIR MONITORING RESULTS

TABLE B-1

GROSS ALPHA ON AIRBORNE PARTICULATES
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Date	Gross Alpha				
	Station 1 Robertson St. 2	Station 2 Pattonville Adm.	Station 3 Pattonville St. 2	Station 4 Spanish Village	Station 5 [a] St. Charles St. 2
05/08/14	1.27E-03 J	8.23E-04 J	4.42E-04 U	3.00E-04 U	1.31E-03 J
05/15/14	4.12E-04 J	5.19E-04 J	3.82E-04 U	1.76E-04 U	5.42E-04 J
05/22/14	5.95E-04 J	8.48E-04 J	5.70E-04 J	8.07E-04 J	3.97E-04 U
05/29/14	4.18E-04 J	4.58E-04 J	7.30E-04 J	6.10E-04 J	6.28E-04 J
06/05/14	4.64E-04 J	1.93E-04 U	6.26E-04 J	3.53E-04 U	1.10E-04 U
06/12/14	4.06E-04 U	3.97E-04 U	3.60E-04 U	3.92E-04 U	2.13E-04 U
06/19/14	7.74E-04 J	4.25E-04 J	7.80E-04 J	6.26E-04 J	5.70E-04 J
06/26/14	3.25E-04 U	8.18E-04 J	5.29E-04 U	3.26E-04 U	3.51E-04 U
07/03/14	7.50E-04 J	9.33E-04 J	5.69E-04 J	3.30E-04 U	9.54E-04 J
07/10/14	4.64E-04 J	7.49E-04 J	7.32E-04 J	1.28E-03 J	8.03E-04 J
07/17/14	8.89E-04 J	1.21E-03 J	8.54E-04 J	9.59E-04 J	7.59E-04 J
07/24/14	5.73E-04 J	5.41E-04 J	2.81E-04 U	5.96E-04 J	5.00E-04 J
07/31/14	9.57E-04	4.50E-04	6.32E-04	9.01E-04	3.71E-04
08/07/14	8.20E-04 J	1.11E-03 J	6.31E-04 J	1.05E-03 J	1.14E-03 J
08/14/14	4.87E-04 J	6.00E-04 J	4.53E-04 J	3.16E-04 U	5.71E-04 J
08/21/14	1.08E-03 J	6.06E-04 J	9.55E-04 J	1.08E-03 J	8.60E-04 J
08/28/14	1.58E-03 J	1.68E-03 J	1.58E-03 J	1.25E-03 J	1.34E-03 J
09/04/14	6.38E-04 J	4.28E-04 U	8.54E-04 J	5.32E-04 U	3.44E-04 U
09/11/14	4.70E-04 U	5.32E-04 U	7.50E-04 U	3.17E-04 U	6.94E-04 U
09/17/14	4.93E-04 U	4.98E-04 U	7.62E-04 U	6.01E-04 U	2.99E-04 U
09/24/14	7.36E-04 U	1.16E-03 U	8.68E-04 U	9.57E-04 U	1.12E-03 U
10/01/14	7.98E-04 J	9.79E-04 J	1.34E-03 J	5.75E-04 J	3.88E-04 U
10/09/14	4.22E-04 J	4.43E-04 J	4.63E-04 J	6.25E-04 J	7.65E-04 J
10/16/14	5.26E-04 J	5.54E-04 J	3.97E-04 J	6.99E-04 J	7.59E-04 J
10/23/14	6.55E-04 J	6.25E-04 J	3.80E-04 U	4.84E-04 J	4.14E-04 U
10/30/14	3.72E-04 U	4.10E-04 J	9.31E-04 J	5.44E-04 J	6.22E-04 J
11/06/14	8.93E-04 J	4.90E-04 U	1.07E-03 J	1.17E-04 U	8.83E-04 J
11/13/14	5.30E-04 J	7.75E-04 J	4.48E-04 U	2.78E-04 U	7.00E-04 J
11/20/14	7.30E-04 J	1.10E-03 J	9.04E-04 J	9.68E-04 J	5.75E-04 J
11/26/14	6.45E-04 J	1.36E-03 J	8.26E-04 J	9.95E-04 J	1.65E-03 J
12/04/14	7.58E-04 J	6.13E-04 J	8.38E-04 J	9.74E-04 J	1.42E-03 J
12/11/14	1.26E-03 J	6.24E-04 J	1.10E-03 J	6.20E-04 J	5.46E-04 J
12/17/14	1.63E-03 J	1.17E-03 J	9.61E-04 J	6.12E-04 J	7.85E-04 J
12/23/14	5.43E-04 J	1.09E-03 J	8.99E-04 J	1.38E-03 J	8.75E-04 J
12/31/14	1.99E-04 U	7.07E-04 J	3.01E-04 U	5.46E-04 J	5.10E-04 J
01/06/15	7.50E-04 J	1.06E-03 J	6.25E-04 J	1.18E-03 J	9.24E-04 J
01/14/15	4.11E-04 U	5.01E-04 J	4.60E-04 J	8.67E-04 J	7.20E-04 J
01/21/15	5.81E-04 J	4.56E-04 U	3.75E-04 U	4.74E-04 J	2.45E-04 U
01/28/15	3.86E-04 J	6.44E-04 J	1.02E-04 U	4.00E-04 U	3.53E-04 U
02/11/15	1.11E-03 J	1.10E-03 J	7.10E-04 J	8.54E-04 J	1.13E-03 J
No. of Detects	32	32	27	26	28
No. of Samples	40	40	40	40	40
Minimum	1.99E-04	1.93E-04	1.02E-04	1.17E-04	1.10E-04
Median	6.17E-04	6.25E-04	6.71E-04	6.11E-04	6.61E-04
Maximum	1.63E-03	1.68E-03	1.58E-03	1.38E-03	1.65E-03

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

[a] Reference station

J Indicates an estimated result (result is less than the reporting limit)

U Indicates a non-detected result (result is less than the sample detection limit)

TABLE B-2

GROSS BETA ON AIRBORNE PARTICULATES
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Date	Gross Beta				
	Station 1 Robertson St. 2	Station 2 Pattonville Adm.	Station 3 Pattonville St. 2	Station 4 Spanish Village	Station 5 [a] St. Charles St. 2
05/08/14	1.87E-02	1.73E-02	1.84E-02	1.85E-02	1.72E-02
05/15/14	1.52E-02	1.48E-02	1.54E-02	1.56E-02	1.21E-02 J
05/22/14	1.88E-02	1.87E-02	1.89E-02	1.80E-02	1.72E-02
05/29/14	1.95E-02	1.88E-02	1.82E-02	1.84E-02	1.89E-02
06/05/14	1.53E-02	1.49E-02	1.54E-02	1.48E-02	1.49E-02
06/12/14	1.50E-02	1.62E-02	1.62E-02	1.53E-02	1.37E-02 J
06/19/14	2.01E-02	2.20E-02	2.04E-02	1.94E-02	1.89E-02
06/26/14	1.80E-02	1.93E-02	1.84E-02	1.71E-02	1.80E-02 J
07/03/14	1.62E-02	1.51E-02	1.65E-02	1.75E-02	1.68E-02
07/10/14	1.97E-02	1.88E-02	2.03E-02	2.13E-02	2.04E-02
07/17/14	1.74E-02	1.76E-02	1.74E-02	1.62E-02	1.78E-02
07/24/14	2.49E-02	2.77E-02	2.56E-02	2.67E-02	2.55E-02
07/31/14	2.05E-02	1.98E-02	1.95E-02	1.81E-02	1.92E-02
08/07/14	3.02E-02	3.59E-02	3.20E-02	3.57E-02	3.20E-02
08/14/14	2.23E-02	2.29E-02	2.24E-02	2.28E-02	2.15E-02
08/21/14	2.69E-02	2.42E-02	2.90E-02	2.67E-02	2.75E-02
08/28/14	2.94E-02	3.11E-02	3.06E-02	2.98E-02	3.29E-02
09/04/14	1.95E-02	1.84E-02	2.13E-02	1.97E-02	1.83E-02
09/11/14	1.72E-02	1.89E-02	1.75E-02	1.79E-02	1.80E-02
09/17/14	1.59E-02	1.92E-02	1.81E-02	1.75E-02 J	1.57E-02 J
09/24/14	2.70E-02	2.79E-02	2.71E-02	2.48E-02	2.66E-02
10/01/14	3.27E-02	3.31E-02	3.52E-02	3.70E-02	3.53E-02
10/09/14	1.90E-02	1.51E-02	1.66E-02	1.66E-02	1.79E-02
10/16/14	1.55E-02	1.32E-02 J	1.32E-02 J	1.32E-02 J	1.38E-02 J
10/23/14	1.63E-02	1.81E-02	1.64E-02	1.54E-02	1.59E-02
10/30/14	2.64E-02	4.13E-03 J	2.74E-02	2.67E-02	2.65E-02
11/06/14	1.78E-02	1.58E-02	1.84E-02	1.58E-02 J	1.57E-02
11/13/14	1.59E-02	1.71E-02	1.64E-02	1.53E-02	1.42E-02 J
11/20/14	2.47E-02	2.59E-02	2.45E-02	2.38E-02	2.40E-02
11/26/14	2.95E-02	2.73E-02	3.06E-02	2.74E-02	3.03E-02
12/04/14	2.73E-02	2.74E-02	2.67E-02	2.69E-02	3.15E-02
12/11/14	3.49E-02	3.09E-02	3.53E-02	3.18E-02	3.40E-02
12/17/14	3.57E-02	3.61E-02	3.88E-02	3.39E-02	3.32E-02
12/23/14	2.62E-02	2.72E-02	2.49E-02	2.92E-02	2.42E-02
12/31/14	1.99E-02	2.16E-02	2.13E-02	2.04E-02	2.02E-02
01/06/15	1.89E-02	2.57E-02	2.49E-02	2.42E-02	2.37E-02
01/14/15	1.92E-02	2.11E-02	1.89E-02	2.06E-02	1.94E-02
01/21/15	2.09E-02	2.16E-02	2.00E-02	2.14E-02	1.59E-02
01/28/15	1.15E-02	1.43E-02	1.46E-02	1.32E-02	1.48E-02
02/11/15	2.91E-02	3.12E-02	2.75E-02	2.62E-02	2.73E-02
No. of Detects	40	40	40	40	40
No. of Samples	40	40	40	40	40
Minimum	1.15E-02	4.13E-03	1.32E-02	1.32E-02	1.21E-02
Median	1.96E-02	1.96E-02	2.02E-02	2.01E-02	1.91E-02
Maximum	3.57E-02	3.61E-02	3.88E-02	3.70E-02	3.53E-02

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

[a] Reference station

J Indicates an estimated result (result is less than the reporting limit)

TABLE B-3

URANIUM-238 ON AIRBORNE PARTICULATES
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Date	Uranium-238				
	Station 1 Robertson St. 2	Station 2 Pattonville Adm.	Station 3 Pattonville St. 2	Station 4 Spanish Village	Station 5 [a] St. Charles St. 2
05/08/14	6.22E-04 J	1.35E-04 U	1.47E-04 J	1.73E-04 J	1.59E-04 U
05/15/14	7.68E-05 U	1.29E-04 J	3.86E-04 J	4.18E-05 U	1.01E-04 U
05/22/14	1.71E-04 U	9.47E-04	1.10E-04 U	8.35E-05 U	1.71E-04 U
05/29/14	1.74E-04 U	4.35E-05 U	-4.42E-05 U	3.07E-04 J	3.45E-05 U
06/05/14	1.29E-04 U	3.86E-05 U	8.49E-05 U	2.42E-04 U	-2.25E-05 U
06/12/14	1.59E-04 U	1.59E-04 U	7.23E-05 U	1.19E-04 U	1.02E-04 U
06/19/14	-1.03E-05 U	1.20E-04 U	7.10E-05 U	1.54E-04 U	9.53E-05 U
06/26/14	8.22E-05 U	7.66E-05 U	1.80E-04 J	8.34E-05 U	1.02E-04 U
07/03/14	1.41E-04 J	7.64E-05 J	6.58E-05 J	1.85E-04 J	1.67E-04 J
07/10/14	9.43E-05 J	1.18E-04 J	7.12E-05 U	9.15E-05 J	1.15E-04 J
07/17/14	1.39E-04 J	9.21E-05 U	1.73E-04 J	8.72E-05 U	1.19E-04 J
07/24/14	1.36E-04 J	1.39E-04 J	1.32E-04 J	7.37E-05 J	7.43E-05 U
07/31/14	8.69E-05 J	1.63E-04 J	1.54E-04 J	2.01E-04 J	5.52E-05 J
08/07/14	1.66E-05 U	1.61E-04 J	1.11E-04 J	9.77E-05 U	1.35E-04 J
08/14/14	1.26E-04 J	1.21E-04 J	1.56E-04 J	8.41E-05 U	6.58E-05 U
08/21/14	0.00E+00 U	4.43E-06 U	1.71E-04 U	2.75E-05 U	-2.24E-05 U
08/28/14	4.14E-05 U	2.63E-04 J	2.29E-04 U	8.35E-05 U	7.23E-05 U
09/04/14	9.32E-05 J	9.38E-05 J	7.19E-05	1.34E-04 J	8.51E-05 J
09/11/14	7.01E-05 J	9.50E-05 J	1.18E-04 J	7.37E-05 J	1.66E-04 J
09/17/14	1.55E-04 J	1.31E-04 J	1.49E-04 J	1.62E-04 J	1.45E-04 J
09/24/14	1.67E-04 J	1.86E-04 J	1.06E-04 J	5.50E-05 U	1.35E-04 J
10/01/14	9.00E-05 J	-8.55E-05 U	5.95E-05 U	1.03E-04 U	9.31E-05 U
10/09/14	1.23E-04 J	1.17E-04 J	1.09E-04 J	7.16E-05 U	1.34E-04 J
10/16/14	1.17E-04 U	1.75E-04 J	5.67E-05 U	8.90E-05 U	8.54E-05 U
10/23/14	1.09E-04 J	1.69E-04 J	5.41E-05 U	1.44E-04 J	1.32E-04 J
10/30/14	1.36E-04 U	1.97E-04 J	1.24E-04 U	3.08E-05 U	9.11E-05 U
11/06/14	1.08E-04 U	1.42E-04 J	6.60E-05 U	1.51E-04 U	1.14E-04 U
11/13/14	2.47E-05 U	1.83E-05 U	1.15E-04 U	4.39E-05 U	7.28E-05 U
11/20/14	4.31E-05 U	0.00E+00 U	4.51E-05 U	2.15E-04 U	-1.20E-05 U
11/26/14	9.52E-05 U	1.25E-04 U	1.29E-04 J	7.66E-05 U	1.63E-04 J
12/04/14	5.67E-05 U	0.00E+00 U	8.27E-05 U	1.61E-04 J	1.13E-04 U
12/11/14	2.10E-04 U	4.08E-05 U	1.66E-04 U	1.18E-04 U	1.29E-04 U
12/17/14	1.58E-04 J	1.44E-04 J	1.83E-04 J	6.17E-05 U	1.05E-04 U
12/23/14	6.29E-05 J	1.33E-04 J	1.40E-04 J	1.32E-04 J	1.22E-04 J
12/31/14	-4.45E-05 U	7.34E-05 U	1.13E-04 U	4.41E-05 U	1.45E-05 U
01/06/15	3.04E-05 U	2.05E-04 J	8.94E-05 U	6.79E-05 U	-2.39E-05 U
01/14/15	1.28E-04 J	8.32E-05 U	8.45E-05 J	4.70E-05 U	1.09E-04 U
01/21/15	6.76E-05 U	-5.66E-05 U	2.16E-04 J	1.04E-04 U	8.43E-05 U
No. of Detects	17	21	19	12	13
No. of Samples	38	38	38	38	38
Minimum	-4.45E-05	-8.55E-05	-4.42E-05	2.75E-05	-2.39E-05
Median	1.02E-04	1.21E-04	1.12E-04	9.03E-05	1.02E-04
Maximum	6.22E-04	9.47E-04	3.86E-04	3.07E-04	1.67E-04

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

[a] Reference station

J Indicates an estimated result (result is less than the reporting limit)

U Indicates a non-detected result (result is less than the sample detection limit)

TABLE B-4

THORIUM-230 ON AIRBORNE PARTICULATES
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Date	Thorium-230				
	Station 1 Robertson St. 2	Station 2 Pattonville Adm.	Station 3 Pattonville St. 2	Station 4 Spanish Village	Station 5 [a] St. Charles St. 2
05/08/14	3.51E-04 J	7.74E-04 J	8.74E-04 J	5.14E-04 J	6.88E-04 J
05/15/14	8.73E-04 J	4.10E-04 J	4.33E-04 J	3.05E-04 J	3.98E-04 J
05/22/14	4.37E-03	4.90E-04	5.70E-04	3.77E-04 U	4.21E-04
05/29/14	9.15E-04 J	9.08E-04 J	4.82E-04 J	6.93E-04 J	5.78E-04 J
06/05/14	4.58E-04 J	3.78E-04 J	3.13E-04 J	6.17E-04 J	7.00E-04 J
06/12/14	3.89E-04 J	5.61E-04 J	7.12E-04 J	6.90E-04 J	8.32E-04 J
06/19/14	4.05E-04 J	3.07E-04 U	5.85E-04 J	3.58E-04 J	3.16E-04 J
06/26/14	6.21E-04 J	3.19E-04 U	5.92E-04 J	4.74E-04 J	2.71E-04 U
07/03/14	3.23E-04 J	6.41E-04 J	4.16E-04 J	6.06E-04 J	5.19E-04 J
07/10/14	6.09E-04 J	5.67E-04 J	6.08E-04 J	6.84E-04 J	3.68E-04 J
07/17/14	3.92E-04 J	6.09E-04 J	7.54E-04 J	6.13E-04 J	6.09E-04 J
07/24/14	5.81E-04 J	5.51E-04 J	4.99E-04 J	5.35E-04 J	3.50E-04 J
07/31/14	5.14E-04 J	5.86E-04 J	7.95E-04 J	3.39E-04 J	4.18E-04 J
08/07/14	4.84E-04 J	6.66E-04 J	8.86E-04 J	7.26E-04 J	7.10E-04 J
08/14/14	5.75E-04 J	1.36E-03 J	4.75E-04 J	5.67E-04 J	6.75E-04 J
08/21/14	3.77E-04 U	4.33E-04 U	5.99E-04 U	1.06E-03 J	5.53E-04 U
08/28/14	4.45E-04 J	7.69E-04 J	6.96E-04 J	5.44E-04 J	6.94E-04 J
09/04/14	4.94E-04 J	7.13E-04 J	6.23E-04 J	5.32E-04 J	1.99E-03 J
09/11/14	5.08E-04 J	1.04E-03 J	6.57E-04 J	8.30E-04 J	6.28E-04 J
09/17/14	5.06E-04 J	4.08E-04 J	8.54E-04 J	6.51E-04 J	5.90E-04 J
09/24/14	4.25E-04 J	5.89E-04 J	3.81E-04 J	6.40E-04 J	4.55E-04 J
10/01/14	3.12E-04 J	4.90E-04 J	6.08E-04 J	5.43E-04 J	5.09E-04 J
10/09/14	3.93E-04 J	4.63E-04 J	4.13E-04 J	4.24E-04 J	5.08E-04 J
10/16/14	4.36E-04 J	6.95E-04 J	4.63E-04 J	3.94E-04 J	5.14E-04 J
10/23/14	4.99E-04 J	7.20E-04 J	8.00E-04 J	7.08E-04 J	7.19E-04 J
10/30/14	5.05E-04 J	4.58E-04 J	4.06E-04 J	6.20E-04 J	5.07E-04 J
11/06/14	7.60E-04 J	5.74E-04 J	6.55E-04 J	4.58E-04 J	4.17E-04 J
11/13/14	2.68E-04 J	6.84E-04 J	3.71E-04 J	4.66E-04 J	3.41E-04 J
11/20/14	4.59E-04 J	5.13E-04 J	5.85E-04 J	1.29E-03 J	1.14E-03 J
11/26/14	5.38E-04 J	9.52E-04 J	4.40E-04 J	6.94E-04 J	3.81E-04 J
12/04/14	2.92E-04 J	4.80E-04 J	5.21E-04 J	4.62E-04 J	5.11E-04 J
12/11/14	6.58E-04 J	3.12E-04 U	1.37E-04 U	1.89E-04 U	2.91E-04 J
12/17/14	7.47E-04 J	5.64E-04 J	4.08E-04 J	8.30E-04 J	5.84E-04 J
12/23/14	7.41E-04 J	9.65E-04 J	5.90E-04 J	5.63E-04 J	5.45E-04 J
12/31/14	3.83E-04 J	3.58E-04 U	4.42E-04 J	1.81E-04 U	9.23E-04 J
01/06/15	4.83E-04 J	1.16E-03 J	6.62E-04 J	5.41E-04 J	3.83E-04 J
01/14/15	3.36E-04 J	2.70E-04 J	4.29E-04 J	4.43E-04 J	6.86E-04 J
01/21/15	5.84E-04 J	6.21E-04 J	5.95E-04 J	2.94E-04 J	6.47E-04 J
No. of Detects	37	33	36	35	36
No. of Samples	38	38	38	38	38
Minimum	2.68E-04	2.70E-04	1.37E-04	1.81E-04	2.71E-04
Median	4.89E-04	5.71E-04	5.85E-04	5.44E-04	5.32E-04
Maximum	4.37E-03	1.36E-03	8.86E-04	1.29E-03	1.99E-03

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

[a] Reference station

J Indicates an estimated result (result is less than the reporting limit)

U Indicates a non-detected result (result is less than the sample detection limit)

TABLE B-5

TOTAL ALPHA-EMITTING RADIUM ON AIRBORNE PARTICULATES
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Date	Total Alpha-Emitting Radium [a]				
	Station 1 Robertson St. 2	Station 2 Pattonville Adm.	Station 3 Pattonville St. 2	Station 4 Spanish Village	Station 5 [a] St. Charles St. 2
05/08/14	5.74E-04 U	5.14E-04 U	3.11E-04 U	8.12E-04 U	2.19E-04 U
05/15/14	4.37E-04 J (226)	3.31E-04 J (226)	3.90E-04 J (226)	3.66E-04 J (226)	2.83E-04 U (226)
05/22/14	1.69E-04 U	6.05E-04 U	8.68E-04 U	2.65E-04 U	1.20E-03 U
05/29/14	-8.56E-05 U	5.84E-04 U	3.50E-04 U	5.99E-04 U	3.73E-04 U
06/05/14	-1.05E-04 U	3.32E-04 U	4.01E-04 U	-4.86E-04 U	-4.34E-04 U
06/12/14	8.19E-04 U	4.09E-04 U	-4.04E-05 U	1.40E-05 U	1.26E-03 U
06/19/14	6.40E-04 U	7.83E-04 U	2.97E-04 U	5.38E-04 U	1.13E-03 U
06/26/14	-9.72E-05 U	9.15E-04 U	6.90E-04 U	5.16E-04 U	1.10E-03 J
07/03/14	1.59E-03 U	1.80E-03 J	4.50E-04 U	-3.84E-04 U	0.00E+00 U
07/10/14	3.82E-04 U	1.52E-03 J	4.71E-04 U	1.21E-03 U	2.26E-04 U
07/17/14	1.10E-03 J	1.38E-03	2.01E-03	1.17E-03 U	4.40E-03
07/24/14	5.01E-04 U	3.40E-04 U	5.58E-04 U	1.71E-04 U	2.75E-04 U
07/31/14	7.02E-04 U	8.28E-04 U	1.13E-04 U	7.97E-04 U	5.44E-05 U
08/07/14	-5.75E-05 U	8.45E-05 U	2.63E-04 U	5.15E-04 U	8.81E-06 U
08/14/14	4.49E-04 U	1.01E-05 U	1.01E-03 U	3.44E-04 U	4.68E-04 U
08/21/14	-1.41E-04 U	9.08E-04 U	4.55E-04 U	2.75E-04 U	5.05E-04 U
08/28/14	3.97E-04 U	-2.01E-04 U	-1.28E-05 U	8.35E-04 U	8.36E-04 U
09/04/14	-2.50E-04 U	6.13E-04 U	8.78E-04 J	2.86E-04 U	6.19E-04 U
09/11/14	4.84E-04 U	5.14E-04 U	5.07E-04 U	8.47E-05 U	6.21E-04 U
09/17/14	-1.22E-04 U	-1.09E-04 U	7.01E-04 U	6.67E-04 U	2.14E-04 U
09/24/14	2.94E-04 U	4.72E-04 U	1.12E-03 U	1.48E-04 U	8.30E-04 U
10/01/14	1.08E-03 J	6.18E-04 U	5.49E-04 U	1.30E-03 J	1.23E-03 U
10/09/14	3.61E-04 U	7.57E-04 U	1.63E-04 U	8.15E-04 U	9.99E-04 U
10/16/14	5.79E-04 U	4.72E-04 U	4.13E-04 U	6.67E-04 U	2.80E-04 U
10/23/14	8.06E-04 U	1.08E-03 J	1.08E-03 J	4.58E-04 U	1.10E-03 U
10/30/14	1.10E-03 U	-2.74E-04 U	-5.23E-05 U	9.69E-04 U	-2.14E-04 U
11/06/14	7.67E-04 U	7.04E-04 U	8.52E-04 U	6.67E-04 U	5.32E-04 U
11/13/14	3.31E-04 U	6.40E-04 U	9.47E-06 U	2.51E-04 U	3.90E-04 U
11/20/14	7.78E-04 U	1.37E-04 U	2.95E-04 U	5.08E-04 U	1.69E-04 U
11/26/14	9.21E-04 U	-6.83E-04 U	-1.56E-04 U	1.05E-03 U	5.16E-05 U
12/04/14	7.10E-04 U	1.81E-04 U	-1.42E-04 U	5.09E-04 U	-4.05E-05 U
12/11/14	6.28E-05 U	3.04E-04 U	1.46E-04 U	1.55E-04 U	2.64E-04 U
12/17/14	5.73E-05 U	9.53E-05 U	9.36E-04 U	9.62E-04 U	4.97E-04 U
12/23/14	7.92E-04 J	-1.32E-04 U	6.54E-05 U	5.14E-05 U	1.31E-04 U
12/31/14	6.20E-05 U	3.89E-04 U	2.89E-04 U	1.36E-04 U	2.59E-04 U
01/06/15	7.64E-04 U	4.55E-04 U	4.00E-05 U	1.38E-03 J	7.36E-04 U
01/14/15	1.48E-04 U	1.60E-04 U	2.08E-04 U	1.50E-04 U	3.49E-05 U
01/21/15	1.94E-05 U	3.13E-04 U	2.23E-04 U	9.53E-05 U	5.24E-04 U
No. of Detects	3	4	3	2	2
No. of Samples	37	37	37	37	37
Minimum	-2.50E-04	-6.83E-04	-1.56E-04	-4.86E-04	-4.34E-04
Median	4.49E-04	4.72E-04	3.50E-04	5.09E-04	3.90E-04
Maximum	1.10E-03	1.80E-03	2.01E-03	1.38E-03	4.40E-03

Notes:

All concentrations in picoCuries per cubic meter (pCi/m^3)

[a] Reference station

J Indicates an estimated result (result is less than the reporting limit)

U Indicates a non-detected result (result is less than the sample detection limit)

(226) Indicates the result is from a radium-226 specific laboratory method

TABLE B-6

RADON MONITORING RESULTS
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Weekly Monitoring Period Ending	Average Weekly Radon Concentration				
	Station 1 Robertson St. 2	Station 2 Pattonville Adm.	Station 3 Pattonville St. 2	Station 4 Spanish Village	Station 5[a] St. Charles St. 2
05/02/14	0.26	0.75	0.37 OH	0.83	0.72
05/09/14	0.27	0.34 G1	0.20	0.16 G1 OH	0.17
05/16/14	0.25 OH	0.27 G1 OH	0.27	0.13	0.13 OH
05/23/14	0.87 LV1	0.47 OH	0.21	0.11	0.16 OH
05/30/14	0.24	0.19 G1 LV1	0.29	0.18	0.25 LV1
06/06/14	0.20	0.18 G1	0.18	0.16	0.15
06/13/14	0.26	0.23 G1 OH	0.17 OH	0.17	0.31
06/20/14	0.20	0.15 G1 LV1	0.19 LV1	0.13 LV1	0.46
06/27/14	0.57 LV1	0.63 G1	0.22 OH	-- LV3	0.29 E1
07/03/14	0.19	0.17 E	0.12	-- V1	0.11 OH
07/11/14	0.20	0.16	0.18	0.31 V2 OH	0.14
07/17/14	0.23	0.19	0.25	0.83	0.16
07/25/14	0.28	0.25	0.25	0.31 LV1	0.24 OH
08/01/14	0.28 OH	0.28	0.21	0.20	0.22
08/08/14	0.36	0.48	0.31	0.27	0.30
08/15/14	0.29	0.29	0.37	0.26	0.26
08/22/14	0.28	0.39	0.33	0.33 OH	0.20 OH
08/29/14	0.24	0.22	0.25	0.13	0.22
09/05/14	0.21	0.21 LV1	0.23	0.09	0.18
09/12/14	0.25 OH	0.24	0.62 LV1	0.16	0.27 LV1
09/18/14	0.21 OL	0.29 LV1	0.22	0.24 OH	0.39
09/25/14	0.25	1.81 LV2	1.88 LV1	0.47 LV1	1.45 LV1
10/02/14	0.36	1.28	0.40 OH	0.22 LV2	0.33 LV1
10/10/14	0.23 LV1	0.64	0.30	0.53 LV1	0.28
10/17/14	0.22 OL	0.20	0.21	0.14	0.22
10/24/14	0.28 OH	0.27 LV1	0.26	0.16	0.27 LV1
10/31/14	0.37	0.27	0.34	0.31	0.39 OH
11/07/14	0.27	0.21	0.22	0.16	0.26
11/13/14	0.28	0.22	0.25	0.24	0.30
11/20/14	0.35 OL	0.22	0.35	0.17	0.35
11/26/14	0.33	0.21	0.31	0.24	0.33
12/04/14	0.35	0.35	0.31 OH	0.29	0.31
12/11/14	0.38	0.35	0.37	0.29 E1	0.34
12/17/14	1.01	0.24	1.18 G1 E2	0.95 E1	0.34
12/23/14	0.28 E1	0.23	0.26	0.13	-- E3
12/30/14	0.43	0.26	0.28	0.21	0.59
01/06/15	0.31	0.20	0.28	0.77	0.32
01/13/15	0.28	0.24	0.24	0.14	0.30
01/20/15	0.41	0.25	0.32	0.56	0.39
01/27/15	0.37	0.23	0.51	0.35	0.35

TABLE B-6 (Continued)

RADON MONITORING RESULTS
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Weekly Monitoring Period Ending	Average Weekly Radon Concentration				
	Station 1 Robertson St. 2	Station 2 Pattonville Adm.	Station 3 Pattonville St. 2	Station 4 Spanish Village	Station 5[a] St. Charles St. 2
02/03/15	0.23	0.17	0.27	0.16	0.28
02/10/15	0.33	0.24	0.31	0.16	0.30
02/17/15	0.27	0.18	0.22	0.15	0.30
No. of measurements	43	43	43	41	42
Minimum	0.19	0.15	0.12	0.09	0.11
Median	0.28	0.24	0.27	0.21	0.30
Maximum	1.01	1.81 LV2	1.88 LV1	0.95 E1	1.45 LV1

Notes:
All concentrations in picoCuries per liter (pCi/L)
[a] Reference station

G1 — Final dose reading of pocket ion chamber exceeded the scale of 2.0 mR and a final reading of 2.0 was assumed. The reported radon result may be biased high.

OH / OL — Indicates one of the three replicate radon measurements was identified either a high (OH) or low (OL) outlier based on Dixon's procedure for outlier identification (see U.S. Nuclear Regulatory Commission (NRC) 1475, Chapter 26.4), assuming a probability of erroneously labeling an observation as an outlier (α) of 0.05. The detected outlier is not reflected in the reported mean radon concentration.

LV1/LV2 — Indicates one (LV1) or two (LV2) of the three replicate measurements were not used in the calculation of the reported mean radon concentration because the replicate measurement(s) derived from electret(s) showing reading(s) below 200 volts. Per the manufacturer, unreliable data may result when electret voltage drops below 200 volts.

LV3 — Indicates no mean radon concentration was calculated because each of the three replicate measurements derived from an electret showing a reading below 200 volts.

V1 — No measurement was available due to equipment vandalism.

V2 — Due to equipment vandalism, no gamma measurement was available; therefore, the average of gamma readings from the subsequent 3 weeks at the monitoring station was used.

E1/E2/E3 — Indicates one (E1), two (E2) or three (E3) replicate measurements yielded a negative radon concentration. The negative radon values were not included in the reported mean radon concentration. No mean radon measurement was calculated if all measurements were negative (E3).

APPENDIX C

CALCULATIONS SUPPORTING RADON MEASUREMENTS

TABLE C-1

DETERMINATION OF RADON MEASUREMENTS AND OUTLIER DETECTION
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Field Collected Measurements for Radon Monitoring															Replicate Radon Measurements[2]			Outlier Detection By Dixon's Procedure[3]							
Station	Start Date	Start Time	Stop Date	Stop Time	Sampling Time (days)	E-Perm 1 Start Volts	E-Perm 1 End Volts	E-Perm 2 Start Volts	E-Perm 2 End Volts	E-Perm 3 Start Volts	E-Perm 3 End Volts	Pocket Ion Chamber Start Dose (mR)	Pocket Ion Chamber End Dose (mR)	Gamma Rate[1] (µR/hr)	Radon Measurement 1 (pCi/L)	Radon Measurement 2 (pCi/L)	Radon Measurement 3 (pCi/L)	Usable measurements for Dixon's test	Sufficient Measurements for Dixon's Test?[4]	Dixon's Statistic for smallest observation[5]	Dixon's Statistic for largest observation[6]	Is the smallest measurement a suspected outlier?[7]	Is the largest measurement a suspected outlier?[7]	Are both the smallest and largest measurements suspected outliers?[8]	Mean Radon[9] (pCi/L)
1	04/25/14	10:30	05/02/14	09:30	6.96	777	728	764	708	770	715	0.10	1.30	6.59	0.202	0.302	0.287	3	yes	0.844	0.156	no	no	no	0.26
4	04/25/14	11:45	05/02/14	13:15	7.06	770	713	768	551	765	692	0.05	1.95	10.91	0.000	2.264	0.221	3	yes	0.098	0.902	no	no	no	0.83
2	04/25/14	11:00	05/02/14	13:00	7.08	759	627	770	687	758	681	0.10	1.60	8.24	1.231	0.541	0.464	3	yes	0.101	0.899	no	no	no	0.75
3	04/25/14	11:30	05/02/14	12:15	7.03	766	393	771	706	760	679	0.05	1.60	8.89	4.793	0.255	0.481	3	yes	0.050	0.950	no	yes	no	0.37 OH
5	04/25/14	12:15	05/02/14	12:40	7.02	749	693	774	727	766	590	0.10	1.55	8.02	0.200	0.069	1.890	3	yes	0.072	0.928	no	no	no	0.72
1	05/02/14	09:30	05/09/14	11:00	7.06	728	680	708	663	715	659	0.10	1.20	5.90	0.239	0.203	0.354	3	yes	0.240	0.760	no	no	no	0.27
4	05/02/14	13:15	05/09/14	12:30	6.97	713	591	551	485	692	621	0.00	2.00	11.96	0.891	0.151	0.164	3	yes	0.017	0.983	no	yes	no	0.16 G1 OH
2	05/02/14	13:00	05/09/14	11:45	6.95	627	546	687	585	681	617	0.00	2.00	11.99	0.342	0.618	0.067	3	yes	0.498	0.502	no	no	no	0.34 G1
3	05/02/14	12:15	05/09/14	12:05	6.99	393	329	706	648	679	611	0.05	1.85	10.43	0.297	0.077	0.230	3	yes	0.694	0.306	no	no	no	0.20
5	05/02/14	12:40	05/09/14	13:00	7.01	693	642	727	682	590	530	0.00	1.35	8.02	0.148	0.054	0.314	3	yes	0.361	0.639	no	no	no	0.17
1	05/09/14	11:00	05/16/14	13:50	7.12	680	495	663	609	659	600	0.00	1.30	7.61	2.108	0.217	0.290	3	yes	0.038	0.962	no	yes	no	0.25 OH
4	05/09/14	12:30	05/16/14	14:40	7.09	591	527	485	428	621	554	0.00	1.90	11.17	0.143	0.080	0.174	3	yes	0.665	0.335	no	no	no	0.13
2	05/09/14	11:45	05/16/14	15:00	7.14	546	328	585	507	617	543	0.00	2.00	11.68	2.506	0.310	0.235	3	yes	0.033	0.967	no	yes	no	0.27 G1 OH
3	05/09/14	12:05	05/16/14	15:25	7.14	329	271	648	580	611	540	0.00	1.70	9.92	0.244	0.258	0.317	3	yes	0.187	0.813	no	no	no	0.27
5	05/09/14	13:00	05/16/14	14:15	7.05	642	583	682	628	530	295	0.00	1.60	9.45	0.175	0.089	3.006	3	yes	0.029	0.971	no	yes	no	0.13 OH
1	05/16/14	13:50	05/23/14	13:10	6.97	495	376	609	76	600	548	0.00	1.05	6.27	1.416	LV (8.27)	0.318	2	no	--	--	--	--	--	0.87 LV1
4	05/16/14	14:40	05/23/14	15:20	7.03	527	470	428	374	554	491	0.00	1.85	10.97	0.085	0.077	0.165	3	yes	0.088	0.912	no	no	no	0.11
3	05/16/14	15:25	05/23/14	15:00	6.98	271	221	580	527	540	486	0.00	1.45	8.65	0.244	0.172	0.202	3	yes	0.410	0.590	no	no	no	0.21
2	05/16/14	15:00	05/23/14	13:50	6.95	328	263	507	223	543	475	0.00	1.40	8.39	0.497	4.015	0.437	3	yes	0.017	0.983	no	yes	no	0.47 OH
5	05/16/14	14:15	05/23/14	14:10	7.00	583	535	628	579	295	248	0.00	1.30	7.74	0.159	0.160	0.244	3	yes	0.011	0.989	no	yes	no	0.16 OH
1	05/23/14	13:10	05/30/14	16:30	7.14	376	330	779	730	548	488	0.00	1.25	7.30	0.213	0.135	0.365	3	yes	0.340	0.660	no	no	no	0.24
4	05/23/14	15:20	05/30/14	15:35	7.01	470	407	374	318	491	423	0.00	1.90	11.29	0.181	0.112	0.250	3	yes	0.504	0.496	no	no	no	0.18
3	05/23/14	15:00	05/30/14	16:00	7.04	775	707	527	465	486	420	0.00	1.60	9.47	0.253	0.264	0.344	3	yes	0.128	0.872	no	no	no	0.29
2	05/23/14	13:50	05/30/14	14:30	7.03	263	193	767	692	475	409	0.00	2.00	11.86	LV (0.366)	0.187	0.184	2	no	--	--	--	--	--	0.19 G1 LV1
5	05/23/14	14:10	05/30/14	15:05	7.04	535	477	579	522	248	193	0.00	1.45	8.58	0.262	0.231	LV (0.339)	2	no	--	--	--	--	--	0.25 LV1
5	05/30/14	15:05	06/06/14	15:05	7.00	477	426	522	474	776	724	0.00	1.40	8.33	0.198	0.137	0.117	3	yes	0.241	0.759	no	no	no	0.15
1	05/30/14	16:30	06/06/14	16:34	7.00	330	286	730	684	488	438	0.00	1.20	7.14	0.222	0.130	0.262	3	yes	0.694	0.306	no	no	no	0.20
3	05/30/14	16:00	06/06/14	15:51	6.99	707	643	465	407	420	364	0.00	1.70	10.13	0.182	0.188	0.175	3	yes	0.525	0.475	no	no	no	0.18
4	05/30/14	15:35	06/06/14	14:00	6.93	407	352	318	267	423	363	0.00	1.75	10.52	0.145	0.116	0.220	3	yes	0.280	0.720	no	no	no	0.16
2	05/30/14	14:30	06/06/14	14:39	7.01	770	696	692	618	409	346	0.00	2.00	11.89	0.173	0.206	0.168	3	yes	0.108	0.892	no	no	no	0.18 G1
5	06/06/14	15:08	06/13/14	11:10	6.83	426	369	474	419	724	658	0.00	1.40	8.53	0.322	0.269	0.337	3	yes	0.773	0.227	no	no	no	0.31
1	06/06/14	16:40	06/13/14	15:00	6.93	286	242	684	637	438	381	0.00	1.20	7.21	0.240	0.158	0.396	3	yes	0.346	0.654	no	no	no	0.26
4	06/06/14	14:05	06/13/14	14:13	7.01	352	295	267	215	363	305	0.00	1.80	10.71	0.180	0.134	0.191	3	yes	0.800	0.200	no	no	no	0.17
2	06/06/14	14:42	06/13/14	13:40	6.96	696	620	618	539	346	281	0.00	2.00	11.98	0.234	0.316	0.235	3	yes	0.008	0.992	no	yes	no	0.23 G1 OH
3	06/06/14	15:54	06/13/14	14:35	6.95	643	582	407	351	364	248	0.00	1.70	10.20	0.164	0.182	1.218	3	yes	0.017	0.983	no	yes	no	0.17 OH
5	06/13/14	11:10	06/20/14	12:20	7.05	369	319	419	320	658	605	0.00	1.40	8.28	0.222	0.995	0.165	3	yes	0.068	0.932	no	no	no	0.46
1	06/13/14	15:00	06/20/14	13:25	6.93	242	202	637	593	381	333	0.00	1.20	7.21	0.187	0.127	0.272	3	yes	0.410	0.590	no	no	no	0.20
4	06/13/14	14:13	06/20/14	12:45	6.94	295	243	215	167	305	252	0.00	1.80	10.81	0.122	LV (0.088)	0.135	2	no	--	--	--	--	--	0.13 LV1
2	06/13/14	13:40	06/20/14	11:55	6.93	620	553	539	473	281	153	0.00	2.00	12.03	0.137	0.157	LV (1.4)	2	no	--	--	--	--	--	0.15 G1 LV1
3	06/13/14	14:35	06/20/14	13:05	6.94	582	522	351	295	248	51	0.00	1.70	10.21	0.173	0.207	LV (2.85)	2	no	--	--	--	--	--	0.19 LV1
2	06/20/14	11:55	06/27/14	10:50	6.95	553	472	473	340	774	695	0.00	2.00	11.98	0.381	1.269	0.242	3	yes	0.135	0.865	no	no	no	0.63 G1
3	06/20/14	13:05	06/27/14	11:20	6.93	522	462	295	241	759	685	0.00	1.65	9.92	0.219	0.220	0.327	3	yes	0.014	0.986	no	yes	no	0.22 OH
5	06/20/14	12:20	06/27/14	12:50	7.02	319	265	320	317	605	541	0.00	1.50	8.90	0.269	E(-0.582)	0.304	2	no	--	--	--	--	--	0.29 E
1	06/20/14	13:25	06/27/14	10:15	6.87	202	159	593	543	333	249	0.00	1.20	7.28	LV (0.258)	0.231	0.914	2	no	--	--	--	--	--	0.57 LV1
4	06/20/14	12:45	06/27/14	12:25	6.99	243	-44	167	120	252	196	0.00	1.85	11.03	LV (4.539)	LV (0.07)	LV (0.19)	0	no	--	--	--	--	--	LV3
4	06/27/14	12:25	07/03/14	V1	V1	770	V1	777	V1	769	V1	V1	V1	V1	V1	V1	V1	0	no	--	--	--	--	--	V1
2	06/27/14	10:50	07/03/14	14:30	6.15	472	430	340	361	695	651	0.00	1.15	7.79	0.187	E (-0.941)	0.150	2	no	--	--	--	--	--	0.17 E
3	06/27/14	11:20	07/03/14	15:23	6.17	462	420	782	733	685	639	0.00	1.30	8.78	0.119	0.132	0.114	3	yes	0.265	0.735	no	no	no	0.12
5	06/27/14	12:50	07/03/14	15:00	6.09	265	216	771	728	541	502	0.00	1.15	7.87	0.407	0.115	0.114	3	yes	0.002	0.998	no	yes	no	0.11 OH
1	06/27/14	10:15	07/03/14	16:35	6.26	761	722	543	490	249	208	0.00	1.20	7.98	0.029	0.324	0.224	3	yes	0.662	0.338	no	no	no	0.19
1	07/03/14	16:35	07/11/14	14:33	7.92	722	661	490	429	763	697	0.00	1.60	8.42	0.155	0.235	0.203	3	yes	0.608	0.392	no	no	no	0.20
2	07/03/14	14:30	07/11/14	11:08	7.86	430	375	765	702	651	594	0.00	1.60	8.48	0.174	0.167	0.127	3	yes	0.850	0.150	no	no	no	0.16
3	07/03/14	15:23	07/11/14	14:00	7.94	420	362	733	670	639	576	0.00	1.65	8.66	0.200	0.157	0.188	3	yes	0.712	0.288	no	no	no	0.18
5	07/03/14	15:00	07/11/14	11:40	7.86	775	724	728	669	502	446	0.00	1.50	7.95	0.054	0.166	0.199	3	yes	0.769	0.231	no	no	no	0.14
4	07/03/14	16:00	07/11/14	12:18	7.85	715	632	725	650	529	286	0.00	1.79	9.51	0.367	0.261	2.750	3	yes	0.042	0.958	no	yes	no	0.31 V2 OH
1	07/11/14	14:33	07/17/14	15:38	6.05	661	613	429	383	697	646	0.00	1.20	8.27	0.206	0.256	0.243	3	yes	0.754	0.246	no	no	no	0.23
2	07/11/14	11:08	07/17/14	14:32	6.14	375	332	702	651	594	549	0.00	1.25	8.48	0.193	0.214	0.151	3	yes	0.670	0.330	no	no	no	0.19
3	07/11/14	14:00	07/17/14	13:14	5.97	362	317	670	619	576	525	0.00	1.25	8.73	0.243	0.232	0.267	3	yes	0.318	0.682	no	no	no	0.25
5	07/11/14	11:40	07/17/14	15:11	6.15	724	681	669	620	446	404	0.00	1.20	8.13	0.103	0.216	0.173	3	yes	0.615	0.385	no	no	no	0.16
4	07/11/14	12:18	07/17/14	13:55	6.07	632	500	650	594	286	227	0.00	1.25	8.58	1.629	0.319	0.549	3	yes	0.176	0.824	no	no	no	0.83
1	07/17/14	15:38	07/25/14	08:10	7.69	613	550	383	324	646	577	0.00	1.55	8.40	0.242	0.275	0.310	3	yes	0.488	0.512	no	no	no	0.28
2	07/17/14	14:32	07/25/14	08:30	7.75	332	281	651	583	549	488	0.00	1.50	8.07	0.192	0.311	0.255	3	yes	0.530	0.470	no	no	no	0.25
3	07/17/14	13:14	07/25/14	09:25	7.84	317	262	619	553	525	460	0.00	1.60	8.50	0.219	0.256	0.279	3	yes	0.622	0.378	no	no	no	0.25

TABLE C-1 (Continued)

DETERMINATION OF RADON MEASUREMENTS AND OUTLIER DETECTION
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Field Collected Measurements for Radon Monitoring															Replicate Radon Measurements[2]			Outlier Detection By Dixon's Procedure[3]						
Station	Start Date	Start Time	Stop Date	Stop Time	Sampling Time (days)	E-Perm 1 Start Volts	E-Perm 1 End Volts	E-Perm 2 Start Volts	E-Perm 2 End Volts	E-Perm 3 Start Volts	E-Perm 3 End Volts	Pocket Ion Chamber Start Dose (mR)	Pocket Ion Chamber End Dose (mR)	Gamma Rate[1] (μR/hr)	Radon Measurement 1 (pCi/L)	Radon Measurement 2 (pCi/L)	Radon Measurement 3 (pCi/L)	Usable measurements for Dixon's test	Sufficient Measurements for Dixon's Test?[4]	Dixon's Statistic for smallest observation[5]	Dixon's Statistic for largest observation[6]	Is the smallest measurement a suspected outlier?[7]	Is the largest measurement a suspected outlier?[7]	Are both the smallest and largest measurements suspected outliers?[8]	Mean Radon[9] (pCi/L)
5	07/17/14	15:11	07/25/14	08:50	7.74	681	620	620	531	404	349	0.00	1.45	7.81	0.228	0.625	0.244	3	yes	0.039	0.961	no	yes	no	0.24 OH
4	07/17/14	13:55	07/25/14	09:47	7.83	500	427	594	510	227	143	0.00	2.00	10.65	0.252	0.358	LV (0.573)	2	no	--	--	--	--	--	0.31 LV1
4	07/25/14	09:47	08/01/14	12:30	7.11	427	362	510	442	767	698	0.00	1.90	11.13	0.230	0.237	0.144	3	yes	0.922	0.078	no	no	no	0.20
1	07/25/14	08:10	08/01/14	11:01	7.12	550	490	324	270	577	514	0.00	1.45	8.49	0.284	0.283	0.317	3	yes	0.009	0.991	no	yes	no	0.28 OH
2	07/25/14	08:30	08/01/14	11:32	7.13	281	227	583	526	488	432	0.00	1.40	8.19	0.323	0.247	0.267	3	yes	0.273	0.727	no	no	no	0.28
3	07/25/14	09:25	08/01/14	12:50	7.14	744	689	553	493	460	404	0.00	1.50	8.75	0.124	0.261	0.237	3	yes	0.826	0.174	no	no	no	0.21
5	07/25/14	08:50	08/01/14	12:12	7.14	620	570	531	476	349	298	0.00	1.35	7.88	0.153	0.256	0.263	3	yes	0.934	0.066	no	no	no	0.22
4	08/01/14	12:30	08/08/14	15:50	7.14	362	295	442	369	698	621	0.00	2.00	11.67	0.253	0.307	0.241	3	yes	0.181	0.819	no	no	no	0.27
1	08/01/14	11:01	08/08/14	14:15	7.13	490	427	270	210	514	448	0.00	1.50	8.76	0.333	0.389	0.368	3	yes	0.627	0.373	no	no	no	0.36
2	08/01/14	11:32	08/08/14	14:40	7.13	760	656	526	463	432	375	0.00	1.45	8.47	0.812	0.338	0.285	3	yes	0.100	0.900	no	no	no	0.48
3	08/01/14	12:50	08/08/14	15:20	7.10	689	622	493	428	404	341	0.00	1.60	9.38	0.269	0.323	0.333	3	yes	0.843	0.157	no	no	no	0.31
5	08/01/14	12:12	08/08/14	15:00	7.12	570	514	476	414	298	245	0.00	1.40	8.20	0.237	0.365	0.299	3	yes	0.479	0.521	no	no	no	0.30
5	08/08/14	15:00	08/15/14	09:40	6.78	514	466	414	360	769	718	0.00	1.20	7.38	0.230	0.366	0.195	3	yes	0.206	0.794	no	no	no	0.26
4	08/08/14	15:50	08/15/14	10:10	6.76	295	238	369	308	621	556	0.00	1.70	10.47	0.258	0.290	0.239	3	yes	0.368	0.632	no	no	no	0.26
1	08/08/14	14:15	08/15/14	09:00	6.78	427	373	763	708	448	392	0.00	1.30	7.99	0.317	0.210	0.341	3	yes	0.815	0.185	no	no	no	0.29
2	08/08/14	14:40	08/15/14	09:20	6.78	656	600	463	407	375	325	0.00	1.30	7.99	0.261	0.335	0.271	3	yes	0.144	0.856	no	no	no	0.29
3	08/08/14	15:20	08/15/14	09:55	6.77	622	555	428	372	341	289	0.00	1.30	8.00	0.440	0.350	0.320	3	yes	0.249	0.751	no	no	no	0.37
5	08/15/14	09:40	08/22/14	09:30	6.99	466	415	360	304	718	661	0.00	1.40	8.34	0.203	0.327	0.204	3	yes	0.013	0.987	no	yes	no	0.20 OH
4	08/15/14	10:10	08/22/14	10:50	7.03	760	687	308	246	556	489	0.00	1.60	9.49	0.328	0.368	0.328	3	yes	0.006	0.994	no	yes	no	0.33 OH
1	08/15/14	09:00	08/22/14	08:25	6.98	373	318	708	650	392	333	0.00	1.45	8.66	0.284	0.202	0.342	3	yes	0.590	0.410	no	no	no	0.28
2	08/15/14	09:20	08/22/14	08:55	6.98	600	539	407	350	325	258	0.00	1.40	8.35	0.305	0.323	0.530	3	yes	0.078	0.922	no	no	no	0.39
3	08/15/14	09:55	08/22/14	10:30	7.02	555	496	372	313	289	235	0.00	1.40	8.30	0.291	0.369	0.324	3	yes	0.418	0.582	no	no	no	0.33
3	08/22/14	10:30	08/29/14	10:40	7.01	496	434	313	261	768	708	0.00	1.50	8.92	0.321	0.238	0.188	3	yes	0.379	0.621	no	no	no	0.25
5	08/22/14	09:30	08/29/14	11:32	7.08	415	367	304	254	661	607	0.00	1.35	7.94	0.192	0.267	0.198	3	yes	0.089	0.911	no	no	no	0.22
4	08/22/14	10:50	08/29/14	11:10	7.01	687	620	770	708	489	425	0.00	1.90	11.29	0.149	0.048	0.188	3	yes	0.720	0.280	no	no	no	0.13
1	08/22/14	08:25	08/29/14	09:00	7.02	318	275	650	605	333	288	0.00	1.10	6.52	0.250	0.178	0.278	3	yes	0.720	0.280	no	no	no	0.24
2	08/22/14	08:55	08/29/14	09:30	7.02	539	483	350	297	258	212	0.00	1.45	8.60	0.231	0.259	0.178	3	yes	0.652	0.348	no	no	no	0.22
3	08/29/14	10:40	09/05/14	10:05	6.98	434	375	261	214	708	653	0.00	1.45	8.66	0.323	0.196	0.159	3	yes	0.226	0.774	no	no	no	0.23
5	08/29/14	11:32	09/05/14	09:45	6.93	367	324	254	209	607	558	0.00	1.30	7.82	0.152	0.228	0.168	3	yes	0.207	0.793	no	no	no	0.18
4	08/29/14	11:10	09/05/14	10:32	6.97	620	561	708	649	425	368	0.00	1.85	11.05	0.080	0.049	0.127	3	yes	0.401	0.599	no	no	no	0.09
1	08/29/14	09:00	09/05/14	08:55	7.00	275	236	605	563	288	247	0.00	1.05	6.25	0.219	0.168	0.248	3	yes	0.629	0.371	no	no	no	0.21
2	08/29/14	09:30	09/05/14	09:21	6.99	483	429	297	251	212	169	0.00	1.40	8.34	0.243	0.185	LV (0.166)	2	no	--	--	--	--	--	0.21 LV1
2	09/05/14	09:21	09/12/14	09:45	7.02	429	376	251	204	750	694	0.00	1.35	8.02	0.269	0.241	0.200	3	yes	0.590	0.410	no	no	no	0.24
3	09/05/14	10:05	09/12/14	10:30	7.02	375	276	214	164	653	597	0.00	1.40	8.31	1.033	LV (0.289)	0.211	2	no	--	--	--	--	--	0.62 LV1
5	09/05/14	09:45	09/12/14	11:15	7.06	324	281	209	164	558	504	0.20	1.55	6.78	0.226	LV (0.304)	0.317	2	no	--	--	--	--	--	0.27 LV1
4	09/05/14	10:32	09/12/14	10:10	6.98	561	503	649	587	368	308	0.20	2.00	10.74	0.108	0.134	0.223	3	yes	0.224	0.776	no	no	no	0.16
1	09/05/14	08:55	09/12/14	09:07	7.01	762	710	563	341	247	205	0.00	1.10	6.54	0.246	2.965	0.259	3	yes	0.005	0.995	no	yes	no	0.25 OH
1	09/12/14	09:07	09/18/14	09:15	6.01	710	670	341	307	765	732	0.00	0.90	6.24	0.206	0.207	0.079	3	yes	0.990	0.010	yes	no	no	0.21 OL
2	09/12/14	09:45	09/18/14	10:15	6.02	376	332	204	163	694	640	0.00	1.15	7.96	0.264	LV (0.277)	0.319	2	no	--	--	--	--	--	0.29 LV1
3	09/12/14	10:30	09/18/14	11:12	6.03	276	234	744	693	597	552	0.00	1.20	8.29	0.242	0.228	0.177	3	yes	0.786	0.214	no	no	no	0.22
5	09/12/14	11:15	09/18/14	10:33	5.97	281	245	755	713	504	462	0.20	1.05	4.54	0.390	0.349	0.426	3	yes	0.532	0.468	no	no	no	0.39
4	09/12/14	10:10	09/18/14	10:56	6.03	503	359	587	535	308	259	0.20	1.60	9.67	1.926	0.205	0.270	3	yes	0.038	0.962	no	yes	no	0.24 OH
1	09/18/14	09:15	09/25/14	09:30	7.01	670	617	307	268	732	682	0.00	1.05	6.24	0.308	0.208	0.247	3	yes	0.393	0.607	no	no	no	0.25
2	09/18/14	10:15	09/25/14	10:20	7.00	332	151	163	117	640	477	0.00	1.40	8.33	LV (2.511)	LV (0.24)	1.811	1	no	--	--	--	--	--	1.81 LV2
3	09/18/14	11:12	09/25/14	11:00	6.99	234	186	693	463	552	442	0.00	1.50	8.94	LV (0.204)	2.732	1.036	2	no	--	--	--	--	--	1.88 LV1
5	09/18/14	10:33	09/25/14	10:42	7.01	245	197	713	491	462	411	0.00	1.30	7.73	LV (0.282)	2.659	0.245	2	no	--	--	--	--	--	1.45 LV1
4	09/18/14	10:56	09/25/14	11:20	7.02	359	266	535	474	259	182	0.00	1.80	10.69	0.779	0.164	LV (0.575)	2	no	--	--	--	--	--	0.47 LV1
1	09/25/14	09:30	10/02/14	12:13	7.11	617	547	268	220	682	627	0.00	1.20	7.03	0.506	0.309	0.267	3	yes	0.177	0.823	no	no	no	0.36
3	09/25/14	11:00	10/02/14	11:35	7.02	733	523	463	396	442	383	0.00	1.40	8.30	2.404	0.455	0.338	3	yes	0.057	0.943	no	yes	no	0.40 OH
5	09/25/14	10:42	10/02/14	11:05	7.02	197	152	491	436	411	351	0.00	1.35	8.02	LV (0.228)	0.276	0.389	2	no	--	--	--	--	--	0.33 LV1
2	09/25/14	10:20	10/02/14	10:45	7.02	750	680	755	595	477	324	0.00	1.40	8.31	0.374	1.648	1.829	3	yes	0.876	0.124	no	no	no	1.28
4	09/25/14	11:20	10/02/14	11:55	7.02	266	181	474	407	182	121	0.00	1.95	11.57	LV (0.648)	0.221	LV (0.275)	1	no	--	--	--	--	--	0.22 LV2
1	10/02/14	12:13	10/10/14	11:30	7.97	547	481	220	163	627	566	0.00	1.60	8.36	0.279	LV (0.287)	0.184	2	no	--	--	--	--	--	0.23 LV1
4	10/02/14	11:55	10/10/14	11:45	7.99	181	122	407	343	505	385	0.00	2.00	10.43	LV (0.191)	0.162	0.894	2	no	--	--	--	--	--	0.53 LV1
3	10/02/14	11:35	10/10/14	11:40	8.00	523	457	396	329	383	324	0.00	1.60	8.33	0.287	0.355	0.246	3	yes	0.379	0.621	no	no	no	0.30
5	10/02/14	11:05	10/10/14	11:50	8.03	631	559	436	381	351	294	0.00	1.50	7.78	0.359	0.205	0.265	3	yes	0.393	0.607	no	no	no	0.28
2	10/02/14	10:45	10/10/14	11:35	8.03	680	614	595	449	324	262	0.00	1.55	8.04	0.246	1.336	0.332	3	yes	0.078	0.922	no	no	no	0.64
1	10/10/14	11:30	10/17/14	12:45	7.05	481	427	758	697	566	515	0.00	1.45	8.57	0.221	0.224	0.145	3	yes	0.965	0.035	yes	no	no	0.22 OL
4	10/10/14	11:45	10/17/14	12:26	7.03	757	688	343	288	385	325	0.00	1.90	11.26	0.149	0.109	0.172	3	yes	0.644	0.356	no	no	no	0.14
3	10/10/14	11:40	10/17/14	12:03	7.02	457	403	329	274	324	277	0.00	1.50	8.91	0.211	0.281	0.149	3	yes	0.470	0.530	no	no	no	0.21
5	10/10/14	11:50	10/17/14	11:23	6.98	559	504	381	336	294	249	0.00	1.30	7.76	0.273	0.179	0.211	3	yes	0.341	0.659	no	no	no	0.22
2	10/10/14	11:35	10/17/14	11:05	6.98	614	560	449	401	262	214	0.00	1.40	8.36	0.196	0.162	0.234	3	yes	0.481	0.519	no	no	no	0.20
1	10/17/14	12:45	10/24/14	11:13	6.94	427	375	697	638	515	435	0.00	1.30	7.81	0.277	0.284	0.682	3	yes	0.016	0.984	no	yes	no	0.28 OH

DETERMINATION OF RADON MEASUREMENTS AND OUTLIER DETECTION
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Field Collected Measurements for Radon Monitoring															Replicate Radon Measurements[2]			Outlier Detection By Dixon's Procedure[3]							
Station	Start Date	Start Time	Stop Date	Stop Time	Sampling Time (days)	E-Perm 1 Start Volts	E-Perm 1 End Volts	E-Perm 2 Start Volts	E-Perm 2 End Volts	E-Perm 3 Start Volts	E-Perm 3 End Volts	Pocket Ion Chamber Start Dose (mR)	Pocket Ion Chamber End Dose (mR)	Gamma Rate[1] (µR/hr)	Radon Measurement 1 (pCi/L)	Radon Measurement 2 (pCi/L)	Radon Measurement 3 (pCi/L)	Usable measurements for Dixon's test	Sufficient Measurements for Dixon's Test?[4]	Dixon's Statistic for smallest observation[5]	Dixon's Statistic for largest observation[6]	Is the smallest measurement a suspected outlier?[7]	Is the largest measurement a suspected outlier?[7]	Are both the smallest and largest measurements suspected outliers?[8]	Mean Radon[9] (pCi/L)
2	10/17/14	11:05	10/24/14	09:37	6.94	560	500	401	353	214	166	0.00	1.35	8.11	0.329	0.201	LV (0.277)	2	no	--	--	--	--	--	0.27 LV1
3	10/17/14	12:03	10/24/14	10:35	6.94	403	349	274	224	277	229	0.00	1.40	8.41	0.278	0.265	0.229	3	yes	0.743	0.257	no	no	no	0.26
4	10/17/14	12:26	10/24/14	10:57	6.94	688	618	288	236	325	268	0.00	1.85	11.11	0.215	0.104	0.173	3	yes	0.624	0.376	no	no	no	0.16
5	10/17/14	11:23	10/24/14	09:55	6.94	504	449	336	18	249	203	0.00	1.30	7.81	0.295	LV (5.135)	0.248	2	no	--	--	--	--	--	0.27 LV1
1	10/24/14	11:13	10/31/14	09:30	6.93	375	320	638	566	435	375	0.00	1.40	8.42	0.306	0.456	0.362	3	yes	0.371	0.629	no	no	no	0.37
2	10/24/14	09:37	10/31/14	09:15	6.98	500	448	353	302	765	700	0.00	1.35	8.05	0.227	0.268	0.321	3	yes	0.432	0.568	no	no	no	0.27
3	10/24/14	10:35	10/31/14	09:46	6.97	349	295	764	695	746	677	0.00	1.40	8.37	0.299	0.357	0.364	3	yes	0.892	0.108	no	no	no	0.34
4	10/24/14	10:57	10/31/14	10:08	6.97	618	544	764	683	765	688	0.00	1.85	11.07	0.304	0.337	0.280	3	yes	0.413	0.587	no	no	no	0.31
5	10/24/14	09:55	10/31/14	10:54	7.04	449	388	761	687	763	693	0.00	1.35	7.99	0.386	0.445	0.388	3	yes	0.036	0.964	no	yes	no	0.39 OH
1	10/31/14	09:30	11/07/14	09:24	7.00	320	271	566	513	375	318	0.00	1.35	8.04	0.247	0.218	0.357	3	yes	0.207	0.793	no	no	no	0.27
2	10/31/14	09:15	11/07/14	08:00	6.95	448	397	302	255	700	642	0.00	1.40	8.40	0.211	0.201	0.226	3	yes	0.387	0.613	no	no	no	0.21
3	10/31/14	09:46	11/07/14	08:37	6.95	757	697	695	637	677	617	0.00	1.45	8.69	0.214	0.207	0.242	3	yes	0.203	0.797	no	no	no	0.22
4	10/31/14	10:08	11/07/14	08:58	6.95	544	479	683	616	688	622	0.00	1.90	11.39	0.181	0.152	0.136	3	yes	0.362	0.638	no	no	no	0.16
5	10/31/14	10:54	11/07/14	08:17	6.89	388	337	687	630	693	637	0.00	1.30	7.86	0.278	0.260	0.244	3	yes	0.479	0.521	no	no	no	0.26
1	11/07/14	09:24	11/13/14	09:56	6.02	730	673	513	465	318	278	0.00	1.15	7.96	0.355	0.284	0.210	3	yes	0.514	0.486	no	no	no	0.28
2	11/07/14	08:00	11/13/14	10:23	6.10	397	354	762	710	642	593	0.00	1.20	8.20	0.210	0.235	0.227	3	yes	0.678	0.322	no	no	no	0.22
3	11/07/14	08:37	11/13/14	10:10	6.06	697	648	637	587	617	564	0.00	1.20	8.24	0.210	0.247	0.305	3	yes	0.391	0.609	no	no	no	0.25
4	11/07/14	08:58	11/13/14	10:04	6.05	479	424	616	549	622	566	0.00	1.60	11.03	0.206	0.353	0.162	3	yes	0.231	0.769	no	no	no	0.24
5	11/07/14	08:17	11/13/14	10:16	6.08	337	293	630	580	637	591	0.00	1.05	7.19	0.325	0.321	0.251	3	yes	0.938	0.062	no	no	no	0.30
1	11/13/14	09:56	11/20/14	10:37	7.03	673	607	465	405	759	701	0.00	1.40	8.30	0.347	0.343	0.204	3	yes	0.972	0.028	yes	no	no	0.35 OL
2	11/13/14	10:23	11/20/14	09:10	6.95	354	299	710	648	593	535	0.00	1.55	9.29	0.252	0.217	0.202	3	yes	0.302	0.698	no	no	no	0.22
3	11/13/14	10:10	11/20/14	09:48	6.98	648	584	587	525	564	499	0.00	1.40	8.35	0.331	0.325	0.380	3	yes	0.095	0.905	no	no	no	0.35
4	11/13/14	10:04	11/20/14	10:12	7.01	424	357	549	486	566	497	0.00	2.00	11.90	0.226	0.105	0.189	3	yes	0.693	0.307	no	no	no	0.17
5	11/13/14	10:16	11/20/14	09:27	6.97	764	699	580	518	591	532	0.00	1.30	7.78	0.343	0.371	0.321	3	yes	0.445	0.555	no	no	no	0.35
1	11/20/14	10:37	11/26/14	08:32	5.91	607	553	405	358	701	651	0.00	1.10	7.75	0.384	0.340	0.280	3	yes	0.575	0.425	no	no	no	0.33
2	11/20/14	09:10	11/26/14	08:39	5.98	299	258	648	599	535	486	0.00	1.25	8.71	0.190	0.205	0.247	3	yes	0.270	0.730	no	no	no	0.21
3	11/20/14	09:48	11/26/14	08:52	5.96	584	535	525	473	499	447	0.00	1.20	8.39	0.254	0.330	0.341	3	yes	0.874	0.126	no	no	no	0.31
4	11/20/14	10:12	11/26/14	09:00	5.95	357	303	486	429	497	441	0.00	1.60	11.20	0.250	0.243	0.220	3	yes	0.779	0.221	no	no	no	0.24
5	11/20/14	09:27	11/26/14	09:09	5.99	699	649	518	469	532	483	0.00	1.05	7.31	0.302	0.351	0.345	3	yes	0.889	0.111	no	no	no	0.33
1	11/26/14	08:32	12/04/14	11:31	8.12	553	482	358	295	651	580	0.00	1.50	7.69	0.373	0.345	0.334	3	yes	0.292	0.708	no	no	no	0.35
2	11/26/14	08:39	12/04/14	11:54	8.14	755	651	599	534	486	422	0.00	1.70	8.71	0.624	0.205	0.234	3	yes	0.070	0.930	no	no	no	0.35
3	11/26/14	08:52	12/04/14	11:45	8.12	535	468	473	408	447	378	0.00	1.55	7.95	0.309	0.307	0.373	3	yes	0.032	0.968	no	yes	no	0.31 OH
4	11/26/14	09:00	12/04/14	11:39	8.11	303	233	429	353	441	368	0.00	2.00	10.27	0.295	0.318	0.270	3	yes	0.522	0.478	no	no	no	0.29
5	11/26/14	09:09	12/04/14	11:50	8.11	649	587	469	405	483	421	0.00	1.40	7.19	0.258	0.350	0.317	3	yes	0.643	0.357	no	no	no	0.31
1	12/04/14	11:31	12/11/14	08:34	6.88	482	421	757	689	580	521	0.00	1.30	7.88	0.402	0.393	0.330	3	yes	0.875	0.125	no	no	no	0.38
2	12/04/14	11:54	12/11/14	09:01	6.88	651	573	534	474	422	366	0.00	1.50	9.08	0.500	0.279	0.262	3	yes	0.070	0.930	no	no	no	0.35
3	12/04/14	11:45	12/11/14	08:50	6.88	468	408	408	349	378	317	0.00	1.40	8.48	0.350	0.360	0.408	3	yes	0.184	0.816	no	no	no	0.37
4	12/04/14	11:39	12/11/14	08:41	6.88	744	664	353	286	368	384	0.00	1.95	11.82	0.294	0.289	E(-1.096)	2	no	--	--	--	--	--	0.29 E
5	12/04/14	11:50	12/11/14	08:55	6.88	587	525	405	348	421	365	0.00	1.35	8.18	0.352	0.350	0.326	3	yes	0.934	0.066	no	no	no	0.34
1	12/11/14	08:34	12/17/14	14:02	6.23	421	360	689	636	521	369	0.00	1.10	7.36	0.569	0.318	2.129	3	yes	0.139	0.861	no	no	no	1.01
2	12/11/14	09:01	12/17/14	14:45	6.24	573	488	474	425	366	319	0.00	1.30	8.68	0.809	0.236	0.244	3	yes	0.013	0.987	no	yes	no	0.24
3	12/11/14	08:50	12/17/14	14:30	6.24	408	358	349	236	317	267	0.00	2.00	13.36	E(-0.046)	1.176	E(-0.005)	1	no	--	--	--	--	--	1.18 G1 E2
4	12/11/14	08:41	12/17/14	14:14	6.23	664	E (-13)	763	698	384	251	0.00	1.65	11.03	E	0.221	1.685	2	no	--	--	--	--	--	0.95 E
5	12/11/14	08:55	12/17/14	14:38	6.24	525	424	348	299	365	318	0.00	1.15	7.68	1.190	0.359	0.315	3	yes	0.051	0.949	no	yes	no	0.34
1	12/17/14	14:02	12/23/14	10:30	5.85	360	312	636	590	369	424	0.00	1.15	8.19	0.358	0.212	E(-1.625)	2	no	--	--	--	--	--	0.28 E
2	12/17/14	14:45	12/23/14	11:20	5.86	488	442	425	379	319	276	0.00	1.25	8.89	0.216	0.241	0.226	3	yes	0.420	0.580	no	no	no	0.23
3	12/17/14	14:30	12/23/14	11:12	5.86	358	314	770	717	745	696	0.00	1.15	8.17	0.279	0.284	0.226	3	yes	0.924	0.076	no	no	no	0.26
4	12/17/14	14:14	12/23/14	10:40	5.85	754	699	698	643	750	691	0.00	1.60	11.39	0.099	0.120	0.167	3	yes	0.311	0.689	no	no	no	0.13
5	12/17/14	14:38	12/23/14	11:00	5.85	424	380	299	256	318	277	0.00	2.00	14.25	E (-0.171)	E(-1.39)	E(-0.187)	0	no	--	--	--	--	--	E3
1	12/23/14	10:30	12/30/14	11:56	7.06	312	256	590	508	424	370	0.00	1.35	7.97	0.366	0.639	0.285	3	yes	0.230	0.770	no	no	no	0.43
2	12/23/14	11:20	12/30/14	11:48	7.02	442	388	379	326	714	653	0.00	1.40	8.31	0.258	0.268	0.261	3	yes	0.299	0.701	no	no	no	0.26
3	12/23/14	11:12	12/30/14	11:32	7.01	314	261	717	657	696	637	0.00	1.35	8.02	0.317	0.267	0.260	3	yes	0.122	0.878	no	no	no	0.28
4	12/23/14	10:40	12/30/14	11:25	7.03	699	630	643	572	691	622	0.00	1.85	10.96	0.193	0.245	0.196	3	yes	0.062	0.938	no	no	no	0.21
5	12/23/14	11:00	12/30/14	11:40	7.03	380	329	762	656	751	670	0.00	1.30	7.71	0.276	0.913	0.568	3	yes	0.459	0.541	no	no	no	0.59
1	12/30/14	11:56	01/06/15	10:55	6.96	749	682	508	451	370	318	0.00	1.35	8.08	0.357	0.303	0.278	3	yes	0.312	0.688	no	no	no	0.31
2	12/30/14	11:48	01/06/15	11:30	6.99	388	335	326	276	653	596	0.00	1.50	8.94	0.224	0.199	0.185	3	yes	0.374	0.626	no	no	no	0.20
3	12/30/14	11:32	01/06/15	11:12	6.99	711	648	657	597	637	543	0.00	1.40	8.35	0.292	0.269	0.778	3	yes	0.046	0.954	no	yes	no	0.28
4	12/30/14	11:25	01/06/15	11:05	6.99	630	566	572	449	622	491	0.00	1.90	11.33	0.129	1.056	1.136	3	yes	0.920	0.080	no	no	no	0.77
5	12/30/14	11:40	01/06/15	11:20	6.99	329	279	656	594	670	612	0.00	1.25	7.46	0.303	0.361	0.298	3	yes	0.075	0.925	no	no	no	0.32
1	01/06/15	10:55	01/13/15	13:00	7.09	682	627	451	397	318	269	0.00	1.25	7.35	0.247	0.314	0.286	3	yes	0.580	0.420	no	no	no	0.28
2	01/06/15	11:30	01/13/15	13:35	7.09	335	285	752	691	596	540	0.00	1.40	8.23	0.234	0.246	0.229	3	yes	0.309	0.691	no	no	no	0.24
3	01/06/15	11:12	01/13/15	13:20	7.09	648	592	597	539	543	490	0.00	1.35	7.93	0.231	0.278	0.223	3	yes	0.141	0.859	no	no	no	0.24
4	01/06/15	11:05	01/13/15	13:15	7.09	566	505	449	389	491	428	0.00	1.90	11.17	0.108	0.142	0.170	3	yes	0.541	0.459	no	no	no	0.14

TABLE C-1 (Continued)

DETERMINATION OF RADON MEASUREMENTS AND OUTLIER DETECTION
WEST LAKE LANDFILL OFF-SITE BASELINE AIR MONITORING

Field Collected Measurements for Radon Monitoring															Replicate Radon Measurements[2]			Outlier Detection By Dixon's Procedure[3]							
Station	Start Date	Start Time	Stop Date	Stop Time	Sampling Time (days)	E-Perm 1 Start Volts	E-Perm 1 End Volts	E-Perm 2 Start Volts	E-Perm 2 End Volts	E-Perm 3 Start Volts	E-Perm 3 End Volts	Pocket Ion Chamber Start Dose (mR)	Pocket Ion Chamber End Dose (mR)	Gamma Rate[1] (μR/hr)	Radon Measurement 1 (pCi/L)	Radon Measurement 2 (pCi/L)	Radon Measurement 3 (pCi/L)	Usable measurements for Dixon's test	Sufficient Measurements for Dixon's Test?[4]	Dixon's Statistic for smallest observation[5]	Dixon's Statistic for largest observation[6]	Is the smallest measurement a suspected outlier?[7]	Is the largest measurement a suspected outlier?[7]	Are both the smallest and largest measurements suspected outliers?[8]	Mean Radon[9] (pCi/L)
5	01/06/15	11:20	01/13/15	13:25	7.09	727	669	594	539	612	544	0.00	1.20	7.06	0.295	0.297	0.481	3	yes	0.012	0.988	no	yes	no	0.30
1	01/13/15	13:00	01/20/15	14:30	7.06	627	568	397	342	759	676	0.00	1.30	7.67	0.304	0.332	0.589	3	yes	0.101	0.899	no	no	no	0.41
2	01/13/15	13:35	01/20/15	13:15	6.99	598	534	691	631	540	484	0.00	1.40	8.35	0.351	0.256	0.253	3	yes	0.037	0.963	no	yes	no	0.25
3	01/13/15	13:20	01/20/15	13:50	7.02	592	533	539	479	490	435	0.00	1.30	7.72	0.319	0.354	0.297	3	yes	0.377	0.623	no	no	no	0.32
4	01/13/15	13:15	01/20/15	14:15	7.04	505	440	389	266	428	361	0.00	1.90	11.24	0.196	1.213	0.264	3	yes	0.067	0.933	no	no	no	0.56
5	01/13/15	13:25	01/20/15	13:35	7.01	669	605	539	475	544	485	0.00	1.25	7.43	0.384	0.437	0.359	3	yes	0.320	0.680	no	no	no	0.39
1	01/20/15	14:30	01/27/15	14:25	7.00	568	511	342	287	676	606	0.00	1.30	7.74	0.299	0.360	0.447	3	yes	0.410	0.590	no	no	no	0.37
2	01/20/15	13:15	01/27/15	12:24	6.96	534	476	631	574	484	430	0.00	1.45	8.67	0.266	0.212	0.221	3	yes	0.167	0.833	no	no	no	0.23
3	01/20/15	13:50	01/27/15	13:40	6.99	533	474	479	379	435	382	0.00	1.40	8.34	0.301	0.974	0.246	3	yes	0.075	0.925	no	no	no	0.51
4	01/20/15	14:15	01/27/15	14:00	6.99	440	377	754	653	361	297	0.00	1.90	11.33	0.196	0.601	0.251	3	yes	0.136	0.864	no	no	no	0.35
5	01/20/15	13:35	01/27/15	13:05	6.98	605	545	475	418	485	428	0.00	1.25	7.46	0.351	0.357	0.353	3	yes	0.279	0.721	no	no	no	0.35
1	01/27/15	14:25	02/03/15	15:18	7.04	511	459	755	700	606	552	0.00	1.30	7.70	0.242	0.205	0.239	3	yes	0.915	0.085	no	no	no	0.23
2	01/27/15	12:24	02/03/15	14:20	7.08	476	423	574	523	430	381	0.00	1.45	8.53	0.207	0.142	0.161	3	yes	0.293	0.707	no	no	no	0.17
3	01/27/15	13:40	02/03/15	14:50	7.05	474	421	379	326	382	334	0.00	1.30	7.68	0.271	0.308	0.226	3	yes	0.547	0.453	no	no	no	0.27
4	01/27/15	14:00	02/03/15	15:05	7.05	377	314	653	589	757	689	0.00	1.90	11.24	0.224	0.119	0.135	3	yes	0.156	0.844	no	no	no	0.16
5	01/27/15	13:05	02/03/15	14:35	7.06	545	489	418	369	428	377	0.00	1.25	7.37	0.310	0.249	0.277	3	yes	0.457	0.543	no	no	no	0.28
1	02/03/15	15:18	02/10/15	10:08	6.78	459	407	700	644	552	485	0.00	1.30	7.98	0.271	0.245	0.471	3	yes	0.114	0.886	no	no	no	0.33
2	02/03/15	14:20	02/10/15	10:24	6.84	423	369	523	470	381	330	0.00	1.40	8.53	0.273	0.218	0.241	3	yes	0.411	0.589	no	no	no	0.24
3	02/03/15	14:50	02/10/15	11:00	6.84	421	368	326	274	334	283	0.00	1.30	7.92	0.300	0.324	0.303	3	yes	0.115	0.885	no	no	no	0.31
4	02/03/15	15:05	02/10/15	11:25	6.85	314	258	589	529	689	625	0.00	1.80	10.95	0.185	0.130	0.151	3	yes	0.373	0.627	no	no	no	0.16
5	02/03/15	14:35	02/10/15	10:40	6.84	489	436	369	317	377	327	0.00	1.25	7.62	0.295	0.327	0.290	3	yes	0.141	0.859	no	no	no	0.30
1	02/10/15	10:08	02/17/15	11:54	7.07	407	358	644	589	485	432	0.00	1.25	7.36	0.252	0.260	0.286	3	yes	0.228	0.772	no	no	no	0.27
2	02/10/15	10:24	02/17/15	12:03	7.07	369	318	470	420	330	283	0.00	1.45	8.55	0.217	0.163	0.166	3	yes	0.061	0.939	no	no	no	0.18
3	02/10/15	11:00	02/17/15	12:12	7.05	368	317	747	689	768	708	0.00	1.40	8.27	0.238	0.207	0.228	3	yes	0.659	0.341	no	no	no	0.22
4	02/10/15	11:25	02/17/15	12:18	7.04	764	698	529	470	625	562	0.00	1.80	10.66	0.146	0.135	0.157	3	yes	0.528	0.472	no	no	no	0.15
5	02/10/15	10:40	02/17/15	12:22	7.07	436	385	317	269	327	278	0.00	1.20	7.07	0.294	0.291	0.304	3	yes	0.242	0.758	no	no	no	0.30

Notes

1 Gamma Rate (μR/hr) = [PIC End Dose - PIC Start Dose (mR)] * 1000 (μR/mR) / [Sampling Time (days) * 24 (hr/day)]

2 Radon (pCi/L) = (SV - EV - 0.066667*D)/(D * CF) - (Gamma x G), where SV = Start Volts, EV = End Volts, D = Sampling Time (days), CF = A + B*[(SV + EV)/2], Gamma = Gamma Rate (μR/hr), A = 7.2954, B = 0.004293, G = 0.07

3 Outlier detection based on Dixon's procedure (see U.S. Nuclear Regulatory Commission (NRC) 1475, Chapter 26.4), assuming a probability of erroneously labeling an observation as an outlier (α) of 0.05.

4 At least three usable measurements are needed for Dixon's procedure. "--" indicates no value because Dixon's procedure was not used.

5 Dixon's statistic for smallest observation = $(y_2 - y_1) / (y_n - y_1)$, where y_2 is second smallest measurement, y_1 is the smallest measurement, and y_n is largest measurement

6 Dixon's statistic for largest observation = $(y_n - y_{(n-1)}) / (y_n - y_1)$, where y_n is largest measurement, $y_{(n-1)}$ is the second largest measurement, and y_1 is the smallest measurement

7 The observation is a suspected outlier if its test statistic is larger than Dixon's criterion ($P_{1-\alpha}$). From NRC 1475, Table T-23, $P_{1-\alpha}$ is 0.941 for α = 0.05 and three measurements.

8 Dixon's test does not allow both the smallest and the largest measurements to be declared outliers.

9 Detected outliers are not reflected in the reported mean radon concentration.

mR milliRoentgen   μR/hr microRoentgen per hour   pCi/L picoCuries per liter

Data Qualifiers

E/E1/E2/E3	Indicates one (E1), two (E2), or three (E3) of the three replicate measurements yielded a negative radon concentration. The negative radon values were not included in the reported mean radon concentration.
G1	Final dose reading of pocket ion chamber exceeded the scale of 2.0 mR and a final reading of 2.0 was assumed. The reported radon result may be biased high.
LV ( )	Replicate measurement associated with eletret having an ending measurement below 200 volts. Per the manufacturer, unreliable data may result when electret voltage drops below 200 volts.
LV1/LV2	Indicates one (LV1) or two (LV2) of the three replicate measurements were not used in the calculation of the reported mean radon concentration because the measurement derived from an electret showing a reading below 200 volts.
LV3	Indicates no mean radon concentration was calculated because each of the three replicate measurements derived from an electret showing a reading below 200 volts.
OH / OL	Indicates one of the three replicate radon measurements was identified as either a high (OH) or low (OL) outlier based on Dixon's procedure for outlier identification.
V1	No measurement was available due to equipment vandalism.
V2	Due to equipment vandalism, no gamma measurement was available; therefore, the average of gamma readings from the subsequent 3 weeks at the monitoring station was used.

APPENDIX D

STATISTICAL ANALYSES

```
> for(i in c(2,6,7,8,10)){ #1:length(analyte)){
+   #make subset
+   kwdata<-subset(rad, Analyte==analyte[i])
+   kwdata<-kwdata[c("Station", "Date_Collected","Result")]
+
+   #format a table for printing
+   kwdata.wide<-dcast(kwdata, Date_Collected ~ Station, value.var="Result",  na.rm = FALSE)
+   kwdata.wide<-kwdata.wide[order(as.Date(kwdata.wide$Date_Collected, "%m/%d/%Y")),]
+   print(paste(analyte[i],"data for Kruskal-Wallis Test"))
+   print(kwdata.wide, row.names = FALSE)
+
+   if(length(unique(kwdata$Station))>=2){
+
+     #run the Kruskal-Wallis test
+     kw<-kruskal.test(kwdata$Result,factor(kwdata$Station))
+     print(kw)
+
+     #if p value is equal to or less than 0.05, then run the post-hoc analysis
+     if(kw$p.value<=0.05){
+       kwmc<-kruskalmc(kwdata$Result, kwdata$Station)
+       print(kwmc)
+     }
+
+     #Friedman's Test for Radon Data
+     ftdata.wide<-na.omit(kwdata.wide)              #remove incomplete datasets
+     print(paste(analyte[i],"data for Friedman's Test"))
+     print(ftdata.wide)
+     f<-friedman.test(as.matrix(ftdata.wide[2:6]))    #run Friedman's test
+     print(f)
+     #if p value is equal to or less than 0.05, then run the post-hoc analysis
+     if(f$p.value<=0.05){
+       fmc<-friedmanmc(as.matrix(ftdata.wide[2:6])) #run Post hoc test
+       print(fmc)
+     }
+   }
+ }
[1] "Thorium-230 data for Kruskal-Wallis Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
       5/8/2014  0.000351  0.000774  0.000874  0.000514  0.000688
      5/15/2014  0.000873  0.000410  0.000433  0.000305  0.000398
      5/22/2014  0.004370  0.000490  0.000570  0.000377  0.000421
      5/29/2014  0.000915  0.000908  0.000482  0.000693  0.000578
       6/5/2014  0.000458  0.000378  0.000313  0.000617  0.000700
      6/12/2014  0.000389  0.000561  0.000712  0.000690  0.000832
      6/19/2014  0.000405  0.000307  0.000585  0.000358  0.000316
      6/26/2014  0.000621  0.000319  0.000592  0.000474  0.000271
       7/3/2014  0.000323  0.000641  0.000416  0.000606  0.000519
      7/10/2014  0.000609  0.000567  0.000608  0.000684  0.000368
      7/17/2014  0.000392  0.000609  0.000754  0.000613  0.000609
      7/24/2014  0.000581  0.000551  0.000499  0.000535  0.000350
      7/31/2014  0.000514  0.000586  0.000795  0.000339  0.000418
       8/7/2014  0.000484  0.000666  0.000886  0.000726  0.000710
      8/14/2014  0.000575  0.001360  0.000475  0.000567  0.000675
      8/21/2014  0.000377  0.000433  0.000599  0.001060  0.000553
      8/28/2014  0.000445  0.000769  0.000696  0.000544  0.000694
       9/4/2014  0.000494  0.000713  0.000623  0.000532  0.001990
      9/11/2014  0.000508  0.001040  0.000657  0.000830  0.000628
      9/17/2014  0.000506  0.000408  0.000854  0.000651  0.000590
      9/24/2014  0.000425  0.000589  0.000381  0.000640  0.000455
      10/1/2014  0.000312  0.000490  0.000608  0.000543  0.000509
      10/9/2014  0.000393  0.000463  0.000413  0.000424  0.000508
     10/16/2014  0.000436  0.000695  0.000463  0.000394  0.000514
     10/23/2014  0.000499  0.000720  0.000800  0.000708  0.000719
     10/30/2014  0.000505  0.000458  0.000406  0.000620  0.000507
      11/6/2014  0.000760  0.000574  0.000655  0.000458  0.000417
     11/13/2014  0.000268  0.000684  0.000371  0.000466  0.000341
     11/20/2014  0.000459  0.000513  0.000585  0.001290  0.001140
     11/26/2014  0.000538  0.000952  0.000440  0.000694  0.000381
      12/4/2014  0.000292  0.000480  0.000521  0.000462  0.000511
     12/11/2014  0.000658  0.000312  0.000137  0.000189  0.000291
     12/17/2014  0.000747  0.000564  0.000408  0.000830  0.000584
     12/23/2014  0.000741  0.000965  0.000590  0.000563  0.000545
     12/31/2014  0.000383  0.000358  0.000442  0.000181  0.000923
       1/6/2015  0.000483  0.001160  0.000662  0.000541  0.000383
      1/14/2015  0.000336  0.000270  0.000429  0.000443  0.000686
      1/21/2015  0.000584  0.000621  0.000595  0.000294  0.000647

         Kruskal-Wallis rank sum test

data:  kwdata$Result and factor(kwdata$Station)
```

```
Kruskal-Wallis chi-squared = 4.2534, df = 4, p-value = 0.3728

[1] "Thorium-230 data for Friedman's Test"
   Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
21       5/8/2014  0.000351  0.000774  0.000874  0.000514  0.000688
18      5/15/2014  0.000873  0.000410  0.000433  0.000305  0.000398
19      5/22/2014  0.004370  0.000490  0.000570  0.000377  0.000421
20      5/29/2014  0.000915  0.000908  0.000482  0.000693  0.000578
25       6/5/2014  0.000458  0.000378  0.000313  0.000617  0.000700
22      6/12/2014  0.000389  0.000561  0.000712  0.000690  0.000832
23      6/19/2014  0.000405  0.000307  0.000585  0.000358  0.000316
24      6/26/2014  0.000621  0.000319  0.000592  0.000474  0.000271
29       7/3/2014  0.000323  0.000641  0.000416  0.000606  0.000519
26      7/10/2014  0.000609  0.000567  0.000608  0.000684  0.000368
27      7/17/2014  0.000392  0.000609  0.000754  0.000613  0.000609
28      7/24/2014  0.000581  0.000551  0.000499  0.000535  0.000350
30      7/31/2014  0.000514  0.000586  0.000795  0.000339  0.000418
34       8/7/2014  0.000484  0.000666  0.000886  0.000726  0.000710
31      8/14/2014  0.000575  0.001360  0.000475  0.000567  0.000675
32      8/21/2014  0.000377  0.000433  0.000599  0.001060  0.000553
33      8/28/2014  0.000445  0.000769  0.000696  0.000544  0.000694
38       9/4/2014  0.000494  0.000713  0.000623  0.000532  0.001990
35      9/11/2014  0.000508  0.001040  0.000657  0.000830  0.000628
36      9/17/2014  0.000506  0.000408  0.000854  0.000651  0.000590
37      9/24/2014  0.000425  0.000589  0.000381  0.000640  0.000455
4       10/1/2014  0.000312  0.000490  0.000608  0.000543  0.000509
8       10/9/2014  0.000393  0.000463  0.000413  0.000424  0.000508
5      10/16/2014  0.000436  0.000695  0.000463  0.000394  0.000514
6      10/23/2014  0.000499  0.000720  0.000800  0.000708  0.000719
7      10/30/2014  0.000505  0.000458  0.000406  0.000620  0.000507
12      11/6/2014  0.000760  0.000574  0.000655  0.000458  0.000417
9      11/13/2014  0.000268  0.000684  0.000371  0.000466  0.000341
10     11/20/2014  0.000459  0.000513  0.000585  0.001290  0.001140
11     11/26/2014  0.000538  0.000952  0.000440  0.000694  0.000381
17      12/4/2014  0.000292  0.000480  0.000521  0.000462  0.000511
13     12/11/2014  0.000658  0.000312  0.000137  0.000189  0.000291
14     12/17/2014  0.000747  0.000564  0.000408  0.000830  0.000584
15     12/23/2014  0.000741  0.000965  0.000590  0.000563  0.000545
16     12/31/2014  0.000383  0.000358  0.000442  0.000181  0.000923
3        1/6/2015  0.000483  0.001160  0.000662  0.000541  0.000383
1       1/14/2015  0.000336  0.000270  0.000429  0.000443  0.000686
2       1/21/2015  0.000584  0.000621  0.000595  0.000294  0.000647

         Friedman rank sum test

data:  as.matrix(ftdata.wide[2:6])
Friedman chi-squared = 5.5072, df = 4, p-value = 0.2391

[1] "Uranium-238 data for Kruskal-Wallis Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
       5/8/2014  6.22e-04  1.35e-04  1.47e-04  1.73e-04  1.59e-04
      5/15/2014  7.68e-05  1.29e-04  3.86e-04  4.18e-05  1.01e-04
      5/22/2014  1.71e-04  9.47e-04  1.10e-04  8.35e-05  1.71e-04
      5/29/2014  1.74e-04  4.35e-05 -4.42e-05  3.07e-04  3.45e-05
       6/5/2014  1.29e-04  3.86e-05  8.49e-05  2.42e-04 -2.25e-05
      6/12/2014  1.59e-04  1.59e-04  7.23e-05  1.19e-04  1.02e-04
      6/19/2014 -1.03e-05  1.20e-04  7.10e-05  1.54e-04  9.53e-05
      6/26/2014  8.22e-05  7.66e-05  1.80e-04  8.34e-05  1.02e-04
       7/3/2014  1.41e-04  7.64e-05  6.58e-05  1.85e-04  1.67e-04
      7/10/2014  9.43e-05  1.18e-04  7.12e-05  9.15e-05  1.15e-04
      7/17/2014  1.39e-04  9.21e-05  1.73e-04  8.72e-05  1.19e-04
      7/24/2014  1.36e-04  1.39e-04  1.32e-04  7.37e-05  7.43e-05
      7/31/2014  8.69e-05  1.63e-04  1.54e-04  2.01e-04  5.52e-05
       8/7/2014  1.66e-05  1.61e-04  1.11e-04  9.77e-05  1.35e-04
      8/14/2014  1.26e-04  1.21e-04  1.56e-04  8.41e-05  6.58e-05
      8/21/2014  0.00e+00  4.43e-06  1.71e-04  2.75e-05 -2.24e-05
      8/28/2014  4.14e-05  2.63e-04  2.29e-04  8.35e-05  7.23e-05
       9/4/2014  9.32e-05  9.38e-05  7.19e-05  1.34e-04  8.51e-05
      9/11/2014  7.01e-05  9.50e-05  1.18e-04  7.37e-05  1.66e-04
      9/17/2014  1.55e-04  1.31e-04  1.49e-04  1.62e-04  1.45e-04
      9/24/2014  1.67e-04  1.86e-04  1.06e-04  5.50e-05  1.35e-04
      10/1/2014  9.00e-05 -8.55e-05  5.95e-05  1.03e-04  9.31e-05
      10/9/2014  1.23e-04  1.17e-04  1.09e-04  7.16e-05  1.34e-04
     10/16/2014  1.17e-04  1.75e-04  5.67e-05  8.90e-05  8.54e-05
     10/23/2014  1.09e-04  1.69e-04  5.41e-05  1.44e-04  1.32e-04
     10/30/2014  1.36e-04  1.97e-04  1.24e-04  3.08e-05  9.11e-05
      11/6/2014  1.08e-04  1.42e-04  6.60e-05  1.51e-04  1.14e-04
     11/13/2014  2.47e-05  1.83e-05  1.15e-04  4.39e-05  7.28e-05
     11/20/2014  4.31e-05  0.00e+00  4.51e-05  2.15e-04 -1.20e-05
     11/26/2014  9.52e-05  1.25e-04  1.29e-04  7.66e-05  1.63e-04
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      12/4/2014  5.67e-05  0.00e+00  8.27e-05  1.61e-04  1.13e-04
     12/11/2014  2.10e-04  4.08e-05  1.66e-04  1.18e-04  1.29e-04
     12/17/2014  1.58e-04  1.44e-04  1.83e-04  6.17e-05  1.05e-04
     12/23/2014  6.29e-05  1.33e-04  1.40e-04  1.32e-04  1.22e-04
     12/31/2014 -4.45e-05  7.34e-05  1.13e-04  4.41e-05  1.45e-05
       1/6/2015  3.04e-05  2.05e-04  8.94e-05  6.79e-05 -2.39e-05
      1/14/2015  1.28e-04  8.32e-05  8.45e-05  4.70e-05  1.09e-04
      1/21/2015  6.76e-05 -5.66e-05  2.16e-04  1.04e-04  8.43e-05

         Kruskal-Wallis rank sum test

data:  kwdata$Result and factor(kwdata$Station)
Kruskal-Wallis chi-squared = 1.9155, df = 4, p-value = 0.7513

[1] "Uranium-238 data for Friedman's Test"
   Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
21       5/8/2014  6.22e-04  1.35e-04  1.47e-04  1.73e-04  1.59e-04
18      5/15/2014  7.68e-05  1.29e-04  3.86e-04  4.18e-05  1.01e-04
19      5/22/2014  1.71e-04  9.47e-04  1.10e-04  8.35e-05  1.71e-04
20      5/29/2014  1.74e-04  4.35e-05 -4.42e-05  3.07e-04  3.45e-05
25       6/5/2014  1.29e-04  3.86e-05  8.49e-05  2.42e-04 -2.25e-05
22      6/12/2014  1.59e-04  1.59e-04  7.23e-05  1.19e-04  1.02e-04
23      6/19/2014 -1.03e-05  1.20e-04  7.10e-05  1.54e-04  9.53e-05
24      6/26/2014  8.22e-05  7.66e-05  1.80e-04  8.34e-05  1.02e-04
29       7/3/2014  1.41e-04  7.64e-05  6.58e-05  1.85e-04  1.67e-04
26      7/10/2014  9.43e-05  1.18e-04  7.12e-05  9.15e-05  1.15e-04
27      7/17/2014  1.39e-04  9.21e-05  1.73e-04  8.72e-05  1.19e-04
28      7/24/2014  1.36e-04  1.39e-04  1.32e-04  7.37e-05  7.43e-05
30      7/31/2014  8.69e-05  1.63e-04  1.54e-04  2.01e-04  5.52e-05
34       8/7/2014  1.66e-05  1.61e-04  1.11e-04  9.77e-05  1.35e-04
31      8/14/2014  1.26e-04  1.21e-04  1.56e-04  8.41e-05  6.58e-05
32      8/21/2014  0.00e+00  4.43e-06  1.71e-04  2.75e-05 -2.24e-05
33      8/28/2014  4.14e-05  2.63e-04  2.29e-04  8.35e-05  7.23e-05
38       9/4/2014  9.32e-05  9.38e-05  7.19e-05  1.34e-04  8.51e-05
35      9/11/2014  7.01e-05  9.50e-05  1.18e-04  7.37e-05  1.66e-04
36      9/17/2014  1.55e-04  1.31e-04  1.49e-04  1.62e-04  1.45e-04
37      9/24/2014  1.67e-04  1.86e-04  1.06e-04  5.50e-05  1.35e-04
4       10/1/2014  9.00e-05 -8.55e-05  5.95e-05  1.03e-04  9.31e-05
8       10/9/2014  1.23e-04  1.17e-04  1.09e-04  7.16e-05  1.34e-04
5      10/16/2014  1.17e-04  1.75e-04  5.67e-05  8.90e-05  8.54e-05
6      10/23/2014  1.09e-04  1.69e-04  5.41e-05  1.44e-04  1.32e-04
7      10/30/2014  1.36e-04  1.97e-04  1.24e-04  3.08e-05  9.11e-05
12      11/6/2014  1.08e-04  1.42e-04  6.60e-05  1.51e-04  1.14e-04
9      11/13/2014  2.47e-05  1.83e-05  1.15e-04  4.39e-05  7.28e-05
10     11/20/2014  4.31e-05  0.00e+00  4.51e-05  2.15e-04 -1.20e-05
11     11/26/2014  9.52e-05  1.25e-04  1.29e-04  7.66e-05  1.63e-04
17      12/4/2014  5.67e-05  0.00e+00  8.27e-05  1.61e-04  1.13e-04
13     12/11/2014  2.10e-04  4.08e-05  1.66e-04  1.18e-04  1.29e-04
14     12/17/2014  1.58e-04  1.44e-04  1.83e-04  6.17e-05  1.05e-04
15     12/23/2014  6.29e-05  1.33e-04  1.40e-04  1.32e-04  1.22e-04
16     12/31/2014 -4.45e-05  7.34e-05  1.13e-04  4.41e-05  1.45e-05
3        1/6/2015  3.04e-05  2.05e-04  8.94e-05  6.79e-05 -2.39e-05
1       1/14/2015  1.28e-04  8.32e-05  8.45e-05  4.70e-05  1.09e-04
2       1/21/2015  6.76e-05 -5.66e-05  2.16e-04  1.04e-04  8.43e-05

         Friedman rank sum test

data:  as.matrix(ftdata.wide[2:6])
Friedman chi-squared = 1.7045, df = 4, p-value = 0.7899

[1] "Total Alpha-Emitting Radium data for Kruskal-Wallis Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
       5/8/2014  5.74e-04  5.14e-04  3.11e-04  8.12e-04  2.19e-04
      5/22/2014  1.69e-04  6.05e-04  8.68e-04  2.65e-04  1.20e-03
      5/29/2014 -8.56e-05  5.84e-04  3.50e-04  5.99e-04  3.73e-04
       6/5/2014 -1.05e-04  3.32e-04  4.01e-04 -4.86e-04 -4.34e-04
      6/12/2014  8.19e-04  4.09e-04 -4.04e-05  1.40e-05  1.26e-03
      6/19/2014  6.40e-04  7.83e-04  2.97e-04  5.38e-04  1.13e-03
      6/26/2014 -9.72e-05  9.15e-04  6.90e-04  5.16e-04  1.10e-03
       7/3/2014  1.59e-03  1.80e-03  4.50e-04 -3.84e-04  0.00e+00
      7/10/2014  3.82e-04  1.52e-03  4.71e-04  1.21e-03  2.26e-04
      7/17/2014  1.10e-03  1.38e-03  2.01e-03  1.17e-03  4.40e-03
      7/24/2014  5.01e-04  3.40e-04  5.58e-04  1.71e-04  2.75e-04
      7/31/2014  7.02e-04  8.28e-04  1.13e-04  7.97e-04  5.44e-05
       8/7/2014 -5.75e-05  8.45e-05  2.63e-04  5.15e-04  8.81e-06
      8/14/2014  4.49e-04  1.01e-05  1.01e-03  3.44e-04  4.68e-04
      8/21/2014 -1.41e-04  9.08e-04  4.55e-04  2.75e-04  5.05e-04
      8/28/2014  3.97e-04 -2.01e-04 -1.28e-05  8.35e-04  8.36e-04
       9/4/2014 -2.50e-04  6.13e-04  8.78e-04  2.86e-04  6.19e-04
      9/11/2014  4.84e-04  5.14e-04  5.07e-04  8.47e-05  6.21e-04
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     9/17/2014 -1.22e-04 -1.09e-04  7.01e-04  6.67e-04  2.14e-04
     9/24/2014  2.94e-04  4.72e-04  1.12e-03  1.48e-04  8.30e-04
     10/1/2014  1.08e-03  6.18e-04  5.49e-04  1.30e-03  1.23e-03
     10/9/2014  3.61e-04  7.57e-04  1.63e-04  8.15e-04  9.99e-04
    10/16/2014  5.79e-04  4.72e-04  4.13e-04  6.67e-04  2.80e-04
    10/23/2014  8.06e-04  1.08e-03  1.08e-03  4.58e-04  1.10e-03
    10/30/2014  1.10e-03 -2.74e-04 -5.23e-05  9.69e-04 -2.14e-04
     11/6/2014  7.67e-04  7.04e-04  8.52e-04  6.67e-04  5.32e-04
    11/13/2014  3.31e-04  6.40e-04  9.47e-06  2.51e-04  3.90e-04
    11/20/2014  7.78e-04  1.37e-04  2.95e-04  5.08e-04  1.69e-04
    11/26/2014  9.21e-04 -6.83e-04 -1.56e-04  1.05e-03  5.16e-05
     12/4/2014  7.10e-04  1.81e-04 -1.42e-04  5.09e-04 -4.05e-05
    12/11/2014  6.28e-05  3.04e-04  1.46e-04  1.55e-04  2.64e-04
    12/17/2014  5.73e-05  9.53e-05  9.36e-04  9.62e-04  4.97e-04
    12/23/2014  7.92e-04 -1.32e-04  6.54e-05  5.14e-05  1.31e-04
    12/31/2014  6.20e-05  3.89e-04  2.89e-04  1.36e-04  2.59e-04
      1/6/2015  7.64e-04  4.55e-04  4.00e-05  1.38e-03  7.36e-04
     1/14/2015  1.48e-04  1.60e-04  2.08e-04  1.50e-04  3.49e-05
     1/21/2015  1.94e-05  3.13e-04  2.23e-04  9.53e-05  5.24e-04

         Kruskal-Wallis rank sum test

data:  kwdata$Result and factor(kwdata$Station)
Kruskal-Wallis chi-squared = 0.9533, df = 4, p-value = 0.9168

[1] "Total Alpha-Emitting Radium data for Friedman's Test"
   Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
20       5/8/2014  5.74e-04  5.14e-04  3.11e-04  8.12e-04  2.19e-04
18      5/22/2014  1.69e-04  6.05e-04  8.68e-04  2.65e-04  1.20e-03
19      5/29/2014 -8.56e-05  5.84e-04  3.50e-04  5.99e-04  3.73e-04
24       6/5/2014 -1.05e-04  3.32e-04  4.01e-04 -4.86e-04 -4.34e-04
21      6/12/2014  8.19e-04  4.09e-04 -4.04e-05  1.40e-05  1.26e-03
22      6/19/2014  6.40e-04  7.83e-04  2.97e-04  5.38e-04  1.13e-03
23      6/26/2014 -9.72e-05  9.15e-04  6.90e-04  5.16e-04  1.10e-03
28       7/3/2014  1.59e-03  1.80e-03  4.50e-04 -3.84e-04  0.00e+00
25      7/10/2014  3.82e-04  1.52e-03  4.71e-04  1.21e-03  2.26e-04
26      7/17/2014  1.10e-03  1.38e-03  2.01e-03  1.17e-03  4.40e-03
27      7/24/2014  5.01e-04  3.40e-04  5.58e-04  1.71e-04  2.75e-04
29      7/31/2014  7.02e-04  8.28e-04  1.13e-04  7.97e-04  5.44e-05
33       8/7/2014 -5.75e-05  8.45e-05  2.63e-04  5.15e-04  8.81e-06
30      8/14/2014  4.49e-04  1.01e-05  1.01e-03  3.44e-04  4.68e-04
31      8/21/2014 -1.41e-04  9.08e-04  4.55e-04  2.75e-04  5.05e-04
32      8/28/2014  3.97e-04 -2.01e-04 -1.28e-05  8.35e-04  8.36e-04
37       9/4/2014 -2.50e-04  6.13e-04  8.78e-04  2.86e-04  6.19e-04
34      9/11/2014  4.84e-04  5.14e-04  5.07e-04  8.47e-05  6.21e-04
35      9/17/2014 -1.22e-04 -1.09e-04  7.01e-04  6.67e-04  2.14e-04
36      9/24/2014  2.94e-04  4.72e-04  1.12e-03  1.48e-04  8.30e-04
4       10/1/2014  1.08e-03  6.18e-04  5.49e-04  1.30e-03  1.23e-03
8       10/9/2014  3.61e-04  7.57e-04  1.63e-04  8.15e-04  9.99e-04
5      10/16/2014  5.79e-04  4.72e-04  4.13e-04  6.67e-04  2.80e-04
6      10/23/2014  8.06e-04  1.08e-03  1.08e-03  4.58e-04  1.10e-03
7      10/30/2014  1.10e-03 -2.74e-04 -5.23e-05  9.69e-04 -2.14e-04
12      11/6/2014  7.67e-04  7.04e-04  8.52e-04  6.67e-04  5.32e-04
9      11/13/2014  3.31e-04  6.40e-04  9.47e-06  2.51e-04  3.90e-04
10     11/20/2014  7.78e-04  1.37e-04  2.95e-04  5.08e-04  1.69e-04
11     11/26/2014  9.21e-04 -6.83e-04 -1.56e-04  1.05e-03  5.16e-05
17      12/4/2014  7.10e-04  1.81e-04 -1.42e-04  5.09e-04 -4.05e-05
13     12/11/2014  6.28e-05  3.04e-04  1.46e-04  1.55e-04  2.64e-04
14     12/17/2014  5.73e-05  9.53e-05  9.36e-04  9.62e-04  4.97e-04
15     12/23/2014  7.92e-04 -1.32e-04  6.54e-05  5.14e-05  1.31e-04
16     12/31/2014  6.20e-05  3.89e-04  2.89e-04  1.36e-04  2.59e-04
3        1/6/2015  7.64e-04  4.55e-04  4.00e-05  1.38e-03  7.36e-04
1       1/14/2015  1.48e-04  1.60e-04  2.08e-04  1.50e-04  3.49e-05
2       1/21/2015  1.94e-05  3.13e-04  2.23e-04  9.53e-05  5.24e-04

         Friedman rank sum test

data:  as.matrix(ftdata.wide[2:6])
Friedman chi-squared = 3.3396, df = 4, p-value = 0.5027

[1] "Gross Alpha data for Kruskal-Wallis Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
       5/8/2014  0.001270  0.000823  0.000442  0.000300  0.001310
      5/15/2014  0.000412  0.000519  0.000382  0.000176  0.000542
      5/22/2014  0.000595  0.000848  0.000570  0.000807  0.000397
      5/29/2014  0.000418  0.000458  0.000730  0.000610  0.000628
       6/5/2014  0.000464  0.000193  0.000626  0.000353  0.000110
      6/12/2014  0.000406  0.000397  0.000360  0.000392  0.000213
      6/19/2014  0.000774  0.000425  0.000780  0.000626  0.000570
      6/26/2014  0.000325  0.000818  0.000529  0.000326  0.000351
```

7/3/2014	0.000750	0.000933	0.000569	0.000330	0.000954
7/10/2014	0.000464	0.000749	0.000732	0.001280	0.000803
7/17/2014	0.000889	0.001210	0.000854	0.000959	0.000759
7/24/2014	0.000573	0.000541	0.000281	0.000596	0.000500
7/31/2014	0.000957	0.000450	0.000632	0.000901	0.000371
8/7/2014	0.000820	0.001110	0.000631	0.001050	0.001140
8/14/2014	0.000487	0.000600	0.000453	0.000316	0.000571
8/21/2014	0.001080	0.000606	0.000955	0.001080	0.000860
8/28/2014	0.001580	0.001680	0.001580	0.001250	0.001340
9/4/2014	0.000638	0.000428	0.000854	0.000532	0.000344
9/11/2014	0.000470	0.000532	0.000750	0.000317	0.000694
9/17/2014	0.000493	0.000498	0.000762	0.000601	0.000299
9/24/2014	0.000736	0.001160	0.000868	0.000957	0.001120
10/1/2014	0.000798	0.000979	0.001340	0.000575	0.000388
10/9/2014	0.000422	0.000443	0.000463	0.000625	0.000765
10/16/2014	0.000526	0.000554	0.000397	0.000699	0.000759
10/23/2014	0.000655	0.000625	0.000380	0.000484	0.000414
10/30/2014	0.000372	0.000410	0.000931	0.000544	0.000622
11/6/2014	0.000893	0.000490	0.001070	0.000117	0.000883
11/13/2014	0.000530	0.000775	0.000448	0.000278	0.000700
11/20/2014	0.000730	0.001100	0.000904	0.000968	0.000575
11/26/2014	0.000645	0.001360	0.000826	0.000995	0.001650
12/4/2014	0.000758	0.000613	0.000838	0.000974	0.001420
12/11/2014	0.001260	0.000624	0.001100	0.000620	0.000546
12/17/2014	0.001630	0.001170	0.000961	0.000612	0.000785
12/23/2014	0.000543	0.001090	0.000899	0.001380	0.000875
12/31/2014	0.000199	0.000707	0.000301	0.000546	0.000510
1/6/2015	0.000750	0.001060	0.000625	0.001180	0.000924
1/14/2015	0.000411	0.000501	0.000460	0.000867	0.000720
1/21/2015	0.000581	0.000456	0.000375	0.000474	0.000245
1/28/2015	0.000386	0.000644	0.000102	0.000400	0.000353
2/11/2015	0.001110	0.001100	0.000710	0.000854	0.001130

```
        Kruskal-Wallis rank sum test

data:  kwdata$Result and factor(kwdata$Station)
Kruskal-Wallis chi-squared = 0.9374, df = 4, p-value = 0.9191

[1] "Gross Alpha data for Friedman's Test"
```

	Date_Collected	Station 1	Station 2	Station 3	Station 4	Station 5
23	5/8/2014	0.001270	0.000823	0.000442	0.000300	0.001310
20	5/15/2014	0.000412	0.000519	0.000382	0.000176	0.000542
21	5/22/2014	0.000595	0.000848	0.000570	0.000807	0.000397
22	5/29/2014	0.000418	0.000458	0.000730	0.000610	0.000628
27	6/5/2014	0.000464	0.000193	0.000626	0.000353	0.000110
24	6/12/2014	0.000406	0.000397	0.000360	0.000392	0.000213
25	6/19/2014	0.000774	0.000425	0.000780	0.000626	0.000570
26	6/26/2014	0.000325	0.000818	0.000529	0.000326	0.000351
31	7/3/2014	0.000750	0.000933	0.000569	0.000330	0.000954
28	7/10/2014	0.000464	0.000749	0.000732	0.001280	0.000803
29	7/17/2014	0.000889	0.001210	0.000854	0.000959	0.000759
30	7/24/2014	0.000573	0.000541	0.000281	0.000596	0.000500
32	7/31/2014	0.000957	0.000450	0.000632	0.000901	0.000371
36	8/7/2014	0.000820	0.001110	0.000631	0.001050	0.001140
33	8/14/2014	0.000487	0.000600	0.000453	0.000316	0.000571
34	8/21/2014	0.001080	0.000606	0.000955	0.001080	0.000860
35	8/28/2014	0.001580	0.001680	0.001580	0.001250	0.001340
40	9/4/2014	0.000638	0.000428	0.000854	0.000532	0.000344
37	9/11/2014	0.000470	0.000532	0.000750	0.000317	0.000694
38	9/17/2014	0.000493	0.000498	0.000762	0.000601	0.000299
39	9/24/2014	0.000736	0.001160	0.000868	0.000957	0.001120
5	10/1/2014	0.000798	0.000979	0.001340	0.000575	0.000388
9	10/9/2014	0.000422	0.000443	0.000463	0.000625	0.000765
6	10/16/2014	0.000526	0.000554	0.000397	0.000699	0.000759
7	10/23/2014	0.000655	0.000625	0.000380	0.000484	0.000414
8	10/30/2014	0.000372	0.000410	0.000931	0.000544	0.000622
13	11/6/2014	0.000893	0.000490	0.001070	0.000117	0.000883
10	11/13/2014	0.000530	0.000775	0.000448	0.000278	0.000700
11	11/20/2014	0.000730	0.001100	0.000904	0.000968	0.000575
12	11/26/2014	0.000645	0.001360	0.000826	0.000995	0.001650
18	12/4/2014	0.000758	0.000613	0.000838	0.000974	0.001420
14	12/11/2014	0.001260	0.000624	0.001100	0.000620	0.000546
15	12/17/2014	0.001630	0.001170	0.000961	0.000612	0.000785
16	12/23/2014	0.000543	0.001090	0.000899	0.001380	0.000875
17	12/31/2014	0.000199	0.000707	0.000301	0.000546	0.000510
4	1/6/2015	0.000750	0.001060	0.000625	0.001180	0.000924
1	1/14/2015	0.000411	0.000501	0.000460	0.000867	0.000720
2	1/21/2015	0.000581	0.000456	0.000375	0.000474	0.000245
3	1/28/2015	0.000386	0.000644	0.000102	0.000400	0.000353
19	2/11/2015	0.001110	0.001100	0.000710	0.000854	0.001130

```
          Friedman rank sum test

data:  as.matrix(ftdata.wide[2:6])
Friedman chi-squared = 3.985, df = 4, p-value = 0.408

[1] "Gross Beta data for Kruskal-Wallis Test"
 Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
       5/8/2014    0.0187   0.01730    0.0184    0.0185    0.0172
      5/15/2014    0.0152   0.01480    0.0154    0.0156    0.0121
      5/22/2014    0.0188   0.01870    0.0189    0.0180    0.0172
      5/29/2014    0.0195   0.01880    0.0182    0.0184    0.0189
       6/5/2014    0.0153   0.01490    0.0154    0.0148    0.0149
      6/12/2014    0.0150   0.01620    0.0162    0.0153    0.0137
      6/19/2014    0.0201   0.02200    0.0204    0.0194    0.0189
      6/26/2014    0.0180   0.01930    0.0184    0.0171    0.0180
       7/3/2014    0.0162   0.01510    0.0165    0.0175    0.0168
      7/10/2014    0.0197   0.01880    0.0203    0.0213    0.0204
      7/17/2014    0.0174   0.01760    0.0174    0.0162    0.0178
      7/24/2014    0.0249   0.02770    0.0256    0.0267    0.0255
      7/31/2014    0.0205   0.01980    0.0195    0.0181    0.0192
       8/7/2014    0.0302   0.03590    0.0320    0.0357    0.0320
      8/14/2014    0.0223   0.02290    0.0224    0.0228    0.0215
      8/21/2014    0.0269   0.02420    0.0290    0.0267    0.0275
      8/28/2014    0.0294   0.03110    0.0306    0.0298    0.0329
       9/4/2014    0.0195   0.01840    0.0213    0.0197    0.0183
      9/11/2014    0.0172   0.01890    0.0175    0.0179    0.0180
      9/17/2014    0.0159   0.01920    0.0181    0.0175    0.0157
      9/24/2014    0.0270   0.02790    0.0271    0.0248    0.0266
      10/1/2014    0.0327   0.03310    0.0352    0.0370    0.0353
      10/9/2014    0.0190   0.01510    0.0166    0.0166    0.0179
     10/16/2014    0.0155   0.01320    0.0132    0.0132    0.0138
     10/23/2014    0.0163   0.01810    0.0164    0.0154    0.0159
     10/30/2014    0.0264   0.00413    0.0274    0.0267    0.0265
      11/6/2014    0.0178   0.01580    0.0184    0.0158    0.0157
     11/13/2014    0.0159   0.01710    0.0164    0.0153    0.0142
     11/20/2014    0.0247   0.02590    0.0245    0.0238    0.0240
     11/26/2014    0.0295   0.02730    0.0306    0.0274    0.0303
      12/4/2014    0.0273   0.02740    0.0267    0.0269    0.0315
     12/11/2014    0.0349   0.03090    0.0353    0.0318    0.0340
     12/17/2014    0.0357   0.03610    0.0388    0.0339    0.0332
     12/23/2014    0.0262   0.02720    0.0249    0.0292    0.0242
     12/31/2014    0.0199   0.02160    0.0213    0.0204    0.0202
       1/6/2015    0.0189   0.02570    0.0249    0.0242    0.0237
      1/14/2015    0.0192   0.02110    0.0189    0.0206    0.0194
      1/21/2015    0.0209   0.02160    0.0200    0.0214    0.0159
      1/28/2015    0.0115   0.01430    0.0146    0.0132    0.0148
      2/11/2015    0.0291   0.03120    0.0275    0.0262    0.0273

          Kruskal-Wallis rank sum test

data:  kwdata$Result and factor(kwdata$Station)
Kruskal-Wallis chi-squared = 0.5781, df = 4, p-value = 0.9655

[1] "Gross Beta data for Friedman's Test"
   Date_Collected Station 1 Station 2 Station 3 Station 4 Station 5
23       5/8/2014    0.0187   0.01730    0.0184    0.0185    0.0172
20      5/15/2014    0.0152   0.01480    0.0154    0.0156    0.0121
21      5/22/2014    0.0188   0.01870    0.0189    0.0180    0.0172
22      5/29/2014    0.0195   0.01880    0.0182    0.0184    0.0189
27       6/5/2014    0.0153   0.01490    0.0154    0.0148    0.0149
24      6/12/2014    0.0150   0.01620    0.0162    0.0153    0.0137
25      6/19/2014    0.0201   0.02200    0.0204    0.0194    0.0189
26      6/26/2014    0.0180   0.01930    0.0184    0.0171    0.0180
31       7/3/2014    0.0162   0.01510    0.0165    0.0175    0.0168
28      7/10/2014    0.0197   0.01880    0.0203    0.0213    0.0204
29      7/17/2014    0.0174   0.01760    0.0174    0.0162    0.0178
30      7/24/2014    0.0249   0.02770    0.0256    0.0267    0.0255
32      7/31/2014    0.0205   0.01980    0.0195    0.0181    0.0192
36       8/7/2014    0.0302   0.03590    0.0320    0.0357    0.0320
33      8/14/2014    0.0223   0.02290    0.0224    0.0228    0.0215
34      8/21/2014    0.0269   0.02420    0.0290    0.0267    0.0275
35      8/28/2014    0.0294   0.03110    0.0306    0.0298    0.0329
40       9/4/2014    0.0195   0.01840    0.0213    0.0197    0.0183
37      9/11/2014    0.0172   0.01890    0.0175    0.0179    0.0180
38      9/17/2014    0.0159   0.01920    0.0181    0.0175    0.0157
39      9/24/2014    0.0270   0.02790    0.0271    0.0248    0.0266
5       10/1/2014    0.0327   0.03310    0.0352    0.0370    0.0353
9       10/9/2014    0.0190   0.01510    0.0166    0.0166    0.0179
6      10/16/2014    0.0155   0.01320    0.0132    0.0132    0.0138
```

```
7       10/23/2014    0.0163  0.01810    0.0164    0.0154    0.0159
8       10/30/2014    0.0264  0.00413    0.0274    0.0267    0.0265
13       11/6/2014    0.0178  0.01580    0.0184    0.0158    0.0157
10      11/13/2014    0.0159  0.01710    0.0164    0.0153    0.0142
11      11/20/2014    0.0247  0.02590    0.0245    0.0238    0.0240
12      11/26/2014    0.0295  0.02730    0.0306    0.0274    0.0303
18       12/4/2014    0.0273  0.02740    0.0267    0.0269    0.0315
14      12/11/2014    0.0349  0.03090    0.0353    0.0318    0.0340
15      12/17/2014    0.0357  0.03610    0.0388    0.0339    0.0332
16      12/23/2014    0.0262  0.02720    0.0249    0.0292    0.0242
17      12/31/2014    0.0199  0.02160    0.0213    0.0204    0.0202
4         1/6/2015    0.0189  0.02570    0.0249    0.0242    0.0237
1        1/14/2015    0.0192  0.02110    0.0189    0.0206    0.0194
2        1/21/2015    0.0209  0.02160    0.0200    0.0214    0.0159
3        1/28/2015    0.0115  0.01430    0.0146    0.0132    0.0148
19       2/11/2015    0.0291  0.03120    0.0275    0.0262    0.0273

         Friedman rank sum test

data:  as.matrix(ftdata.wide[2:6])
Friedman chi-squared = 12.4867, df = 4, p-value = 0.01408

Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2    27.5     39.69745      FALSE
1-3    26.0     39.69745      FALSE
1-4     3.0     39.69745      FALSE
1-5    10.5     39.69745      FALSE
2-3     1.5     39.69745      FALSE
2-4    30.5     39.69745      FALSE
2-5    38.0     39.69745      FALSE
3-4    29.0     39.69745      FALSE
3-5    36.5     39.69745      FALSE
4-5     7.5     39.69745      FALSE
```

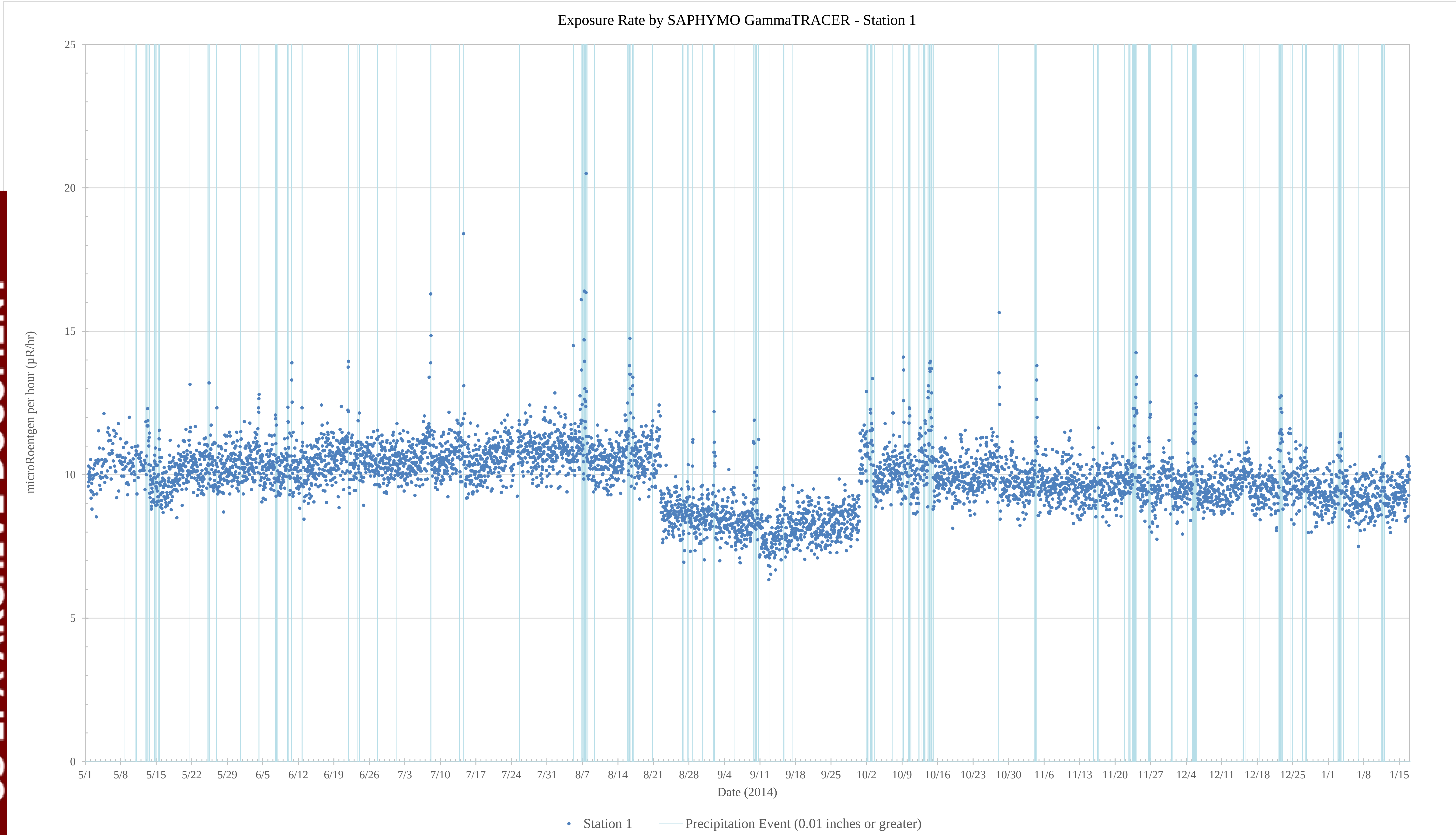
```
> #Kruskal-Wallis and Friedman's Tests for Radon Data
> library(pgirmess)
> library(reshape2)
>
> #load radon measurements
> kwdata<-radon[c("Station.Name", "Stop_Date","result", "run.dixon")]
>
> #If measurements did not meet Data Quality Objectives (DQO) (less than usable replicate measure
ments)
> #then make the value "NA" so that it is not used in the Kruskal-Wallis test
> kwdata$result[kwdata$run.dixon=="no"] <- NA
>
> #format a table for printing
> kwdata.wide<-dcast(kwdata, Stop_Date ~ Station.Name, value.var="result",  na.rm = FALSE)
> kwdata.wide<-kwdata.wide[order(as.Date(kwdata.wide$Stop_Date, "%m/%d/%Y")),]
> print(kwdata.wide, row.names = FALSE)
  Stop_Date Station 1 Station 2 Station 3 Station 4 Station 5
   5/2/2014     0.263     0.746     0.368     0.828     0.720
   5/9/2014     0.266     0.342     0.201     0.157     0.172
  5/16/2014     0.254     0.273     0.273     0.132     0.132
  5/23/2014        NA     0.467     0.206     0.109     0.159
  5/30/2014     0.238        NA     0.287     0.181        NA
   6/6/2014     0.204     0.182     0.182     0.160     0.151
  6/13/2014     0.265     0.235     0.173     0.168     0.309
  6/20/2014     0.195        NA        NA        NA     0.461
  6/27/2014        NA     0.631     0.220        NA        NA
   7/3/2014     0.192        NA     0.122        NA     0.114
  7/11/2014     0.198     0.156     0.182     0.314     0.140
  7/17/2014     0.235     0.186     0.247     0.832     0.164
  7/25/2014     0.276     0.253     0.251        NA     0.236
   8/1/2014     0.283     0.279     0.207     0.204     0.224
   8/8/2014     0.363     0.478     0.308     0.267     0.300
  8/15/2014     0.290     0.289     0.370     0.262     0.263
  8/22/2014     0.276     0.386     0.328     0.328     0.204
  8/29/2014     0.235     0.223     0.249     0.128     0.219
   9/5/2014     0.212        NA     0.226     0.085     0.183
  9/12/2014     0.252     0.236        NA     0.155        NA
  9/18/2014     0.206        NA     0.216     0.237     0.389
  9/25/2014     0.254        NA        NA        NA        NA
  10/2/2014     0.360     1.284     0.396        NA        NA
 10/10/2014        NA     0.638     0.296        NA     0.276
 10/17/2014     0.223     0.197     0.214     0.143     0.221
 10/24/2014     0.281        NA     0.257     0.164        NA
 10/31/2014     0.375     0.272     0.340     0.307     0.387
  11/7/2014     0.274     0.213     0.221     0.156     0.261
 11/13/2014     0.283     0.224     0.254     0.240     0.299
 11/20/2014     0.345     0.223     0.345     0.173     0.345
 11/26/2014     0.335     0.214     0.308     0.237     0.333
  12/4/2014     0.351     0.354     0.308     0.294     0.308
 12/11/2014     0.375     0.347     0.373        NA     0.343
 12/17/2014     1.005     0.240        NA        NA     0.337
 12/23/2014        NA     0.227     0.263     0.128        NA
 12/30/2014     0.430     0.263     0.281     0.212     0.586
   1/6/2015     0.313     0.203     0.280     0.774     0.320
  1/13/2015     0.282     0.236     0.244     0.140     0.296
  1/20/2015     0.408     0.255     0.323     0.558     0.393
  1/27/2015     0.369     0.233     0.507     0.349     0.354
```

```
   2/3/2015      0.229      0.170      0.268      0.159      0.278
  2/10/2015      0.329      0.244      0.309      0.155      0.304
  2/17/2015      0.266      0.182      0.224      0.146      0.296
>
> #run the Kruskal-Wallis test
> kw<-kruskal.test(kwdata$result,factor(kwdata$Station.Name))
> kw

         Kruskal-Wallis rank sum test

data:  kwdata$result and factor(kwdata$Station.Name)
Kruskal-Wallis chi-squared = 13.6471, df = 4, p-value = 0.008511

>
> #if p value is equal to or less than 0.05, then run the post-hoc analysis
> if(kw$p.value<=0.05){
+   kwmc<-kruskalmc(kwdata$result,factor(kwdata$Station.Name))
+   print(kwmc)
+ }
Multiple comparison test after Kruskal-Wallis
p.value: 0.05
Comparisons
                      obs.dif critical.dif difference
Station 1-Station 2 12.879274     34.55404      FALSE
Station 1-Station 3 10.782051     33.85591      FALSE
Station 1-Station 4 43.100679     35.07854       TRUE
Station 1-Station 5  6.879274     34.55404      FALSE
Station 2-Station 3  2.097222     34.55404      FALSE
Station 2-Station 4 30.221405     35.75280      FALSE
Station 2-Station 5  6.000000     35.23835      FALSE
Station 3-Station 4 32.318627     35.07854      FALSE
Station 3-Station 5  3.902778     34.55404      FALSE
Station 4-Station 5 36.221405     35.75280       TRUE
Warning message:
In kruskalmc.default(kwdata$result, factor(kwdata$Station.Name)) :
  31 lines including NA have been omitted
>
> #Friedman's Test for Radon Data
> ftdata.wide<-na.omit(kwdata.wide)              #remove incomplete datasets
> ftdata.wide
    Stop_Date Station 1 Station 2 Station 3 Station 4 Station 5
23   5/2/2014     0.263     0.746     0.368     0.828     0.720
26   5/9/2014     0.266     0.342     0.201     0.157     0.172
22  5/16/2014     0.254     0.273     0.273     0.132     0.132
30   6/6/2014     0.204     0.182     0.182     0.160     0.151
27  6/13/2014     0.265     0.235     0.173     0.168     0.309
31  7/11/2014     0.198     0.156     0.182     0.314     0.140
32  7/17/2014     0.235     0.186     0.247     0.832     0.164
35   8/1/2014     0.283     0.279     0.207     0.204     0.224
39   8/8/2014     0.363     0.478     0.308     0.267     0.300
36  8/15/2014     0.290     0.289     0.370     0.262     0.263
37  8/22/2014     0.276     0.386     0.328     0.328     0.204
38  8/29/2014     0.235     0.223     0.249     0.128     0.219
6  10/17/2014     0.223     0.197     0.214     0.143     0.221
9  10/31/2014     0.375     0.272     0.340     0.307     0.387
13  11/7/2014     0.274     0.213     0.221     0.156     0.261
10 11/13/2014     0.283     0.224     0.254     0.240     0.299
```

```
11 11/20/2014     0.345     0.223     0.345     0.173     0.345
12 11/26/2014     0.335     0.214     0.308     0.237     0.333
18  12/4/2014     0.351     0.354     0.308     0.294     0.308
17 12/30/2014     0.430     0.263     0.281     0.212     0.586
4    1/6/2015     0.313     0.203     0.280     0.774     0.320
1   1/13/2015     0.282     0.236     0.244     0.140     0.296
2   1/20/2015     0.408     0.255     0.323     0.558     0.393
3   1/27/2015     0.369     0.233     0.507     0.349     0.354
21   2/3/2015     0.229     0.170     0.268     0.159     0.278
19  2/10/2015     0.329     0.244     0.309     0.155     0.304
20  2/17/2015     0.266     0.182     0.224     0.146     0.296
> friedman.test(as.matrix(ftdata.wide[2:6]))     #run Friedman's test

         Friedman rank sum test

data:  as.matrix(ftdata.wide[2:6])
Friedman chi-squared = 21.484, df = 4, p-value = 0.0002538

> friedmanmc(as.matrix(ftdata.wide[2:6]))        #run Post hoc test
Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2      34     32.61479       TRUE
1-3      17     32.61479      FALSE
1-4      50     32.61479       TRUE
1-5      19     32.61479      FALSE
2-3      17     32.61479      FALSE
2-4      16     32.61479      FALSE
2-5      15     32.61479      FALSE
3-4      33     32.61479       TRUE
3-5       2     32.61479      FALSE
4-5      31     32.61479      FALSE
>
> #compute ranks by date
> ftdata.wide.ranks<-cbind(ftdata.wide[1], t(apply(ftdata.wide[2:6],1,rank)))
> #show total ranks
> colSums(ftdata.wide.ranks[2:6])
Station 1 Station 2 Station 3 Station 4 Station 5
      105        71        88        55        86
```

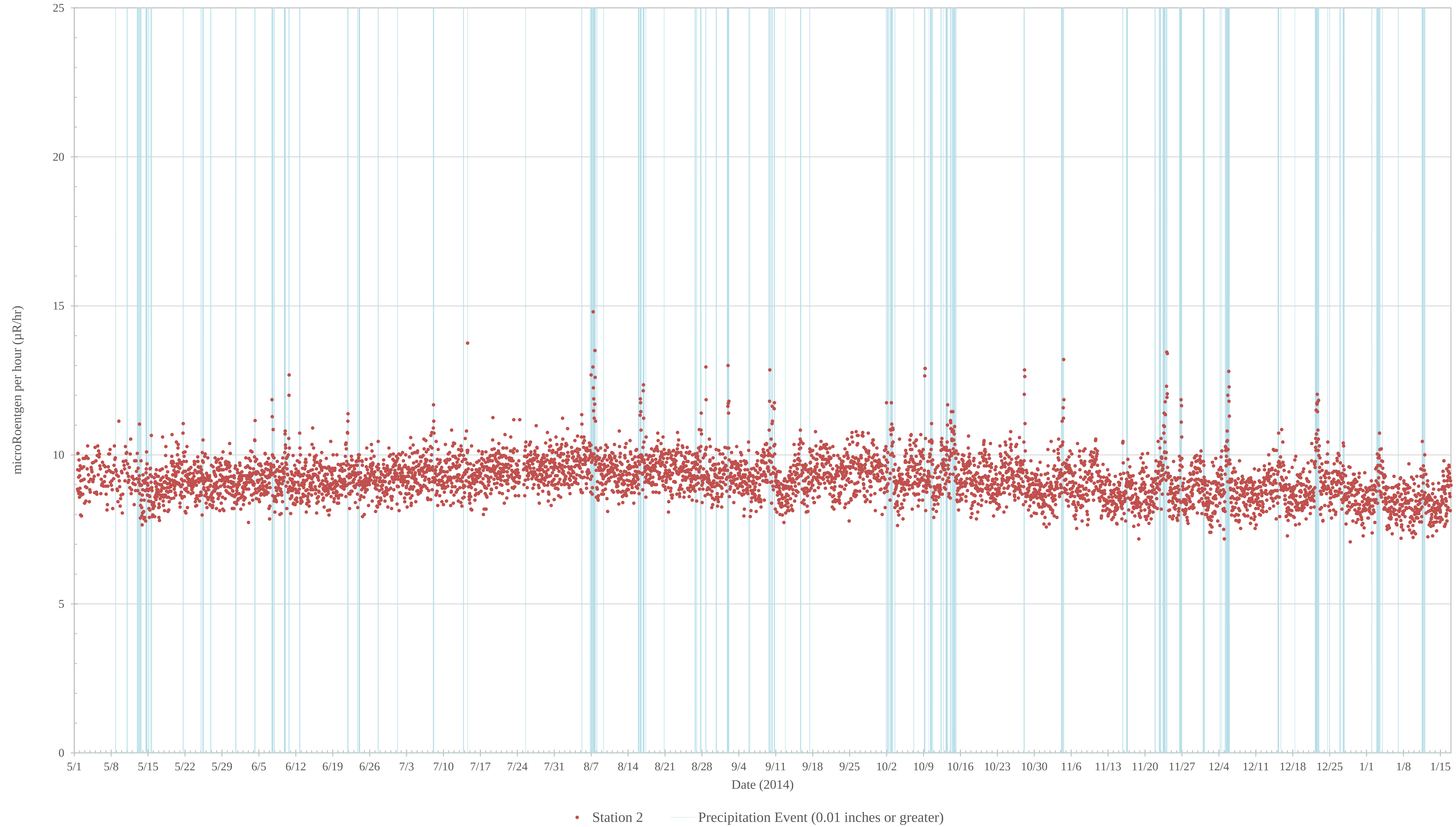
APPENDIX E

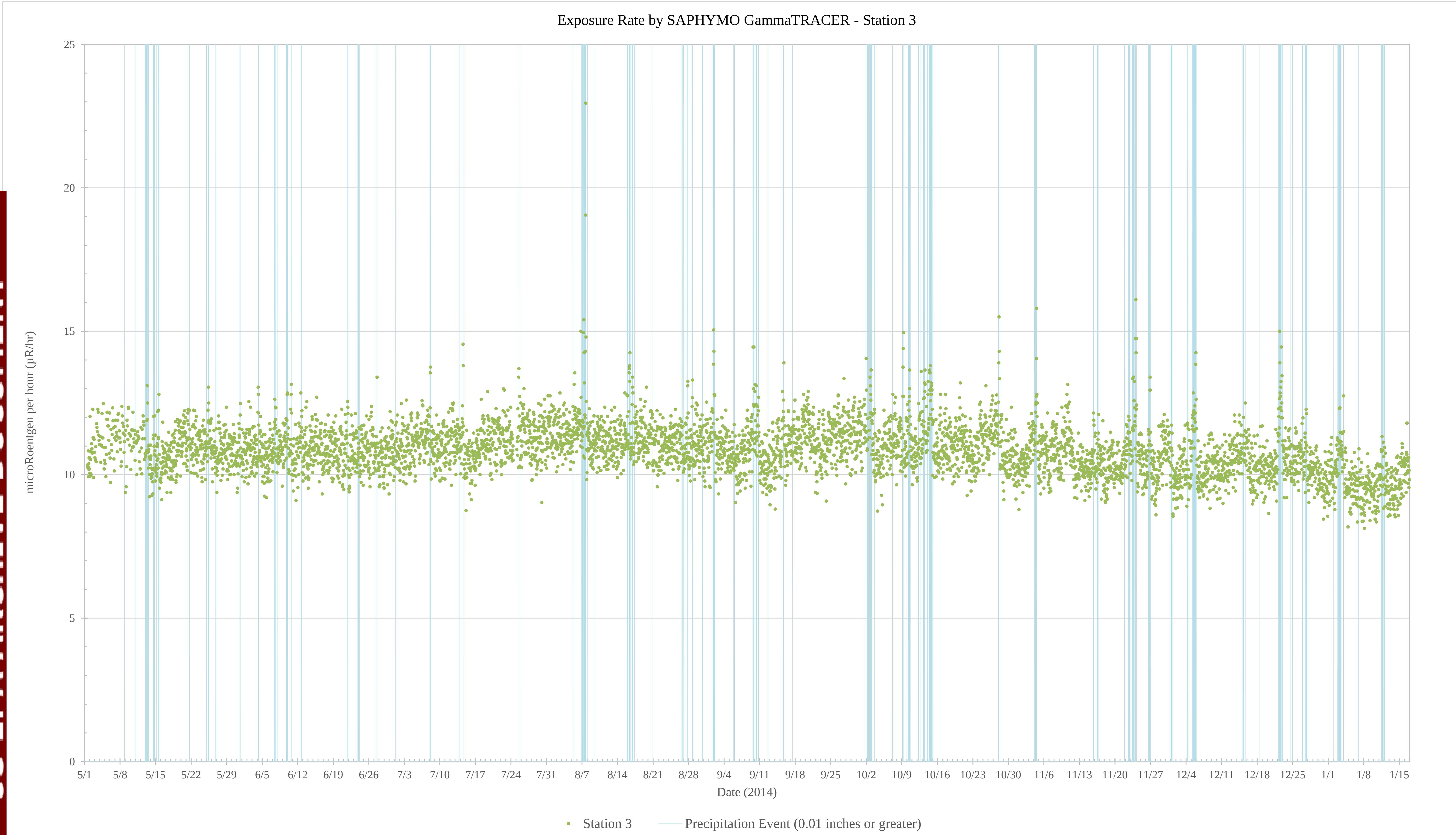
SAPHYMO GAMMATRACER PLOTS



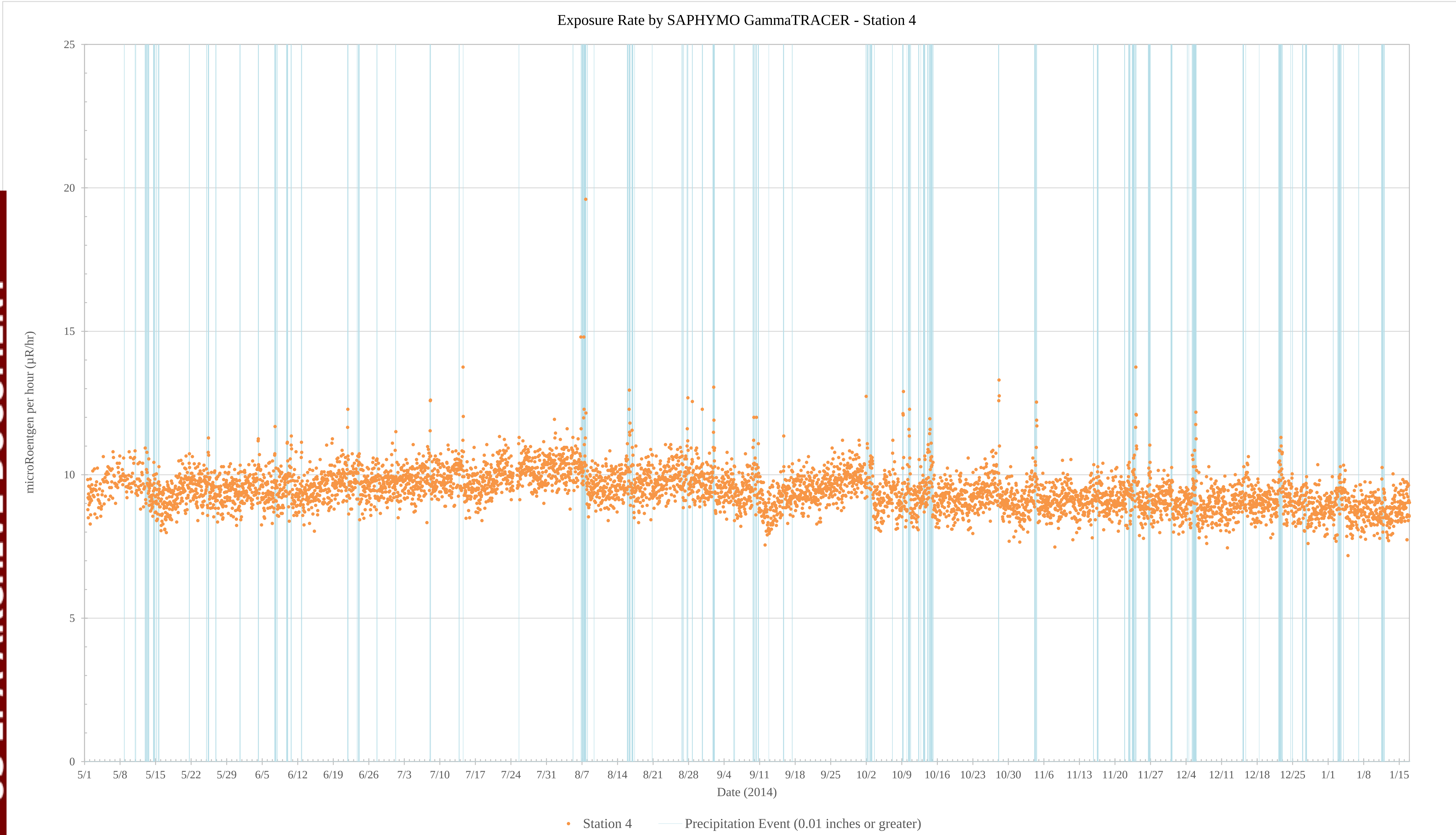
Exposure Rate by SAPHYMO GammaTRACER - Station 1
microRoentgen per hour (µR/hr)
25
20
15
10
5
0
5/1
5/8
5/15
5/22
5/29
6/5
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
9/25
10/2
10/9
10/16
10/23
10/30
11/6
11/13
11/20
11/27
12/4
12/11
12/18
12/25
1/1
1/8
1/15
Date (2014)
Station 1
Precipitation Event (0.01 inches or greater)

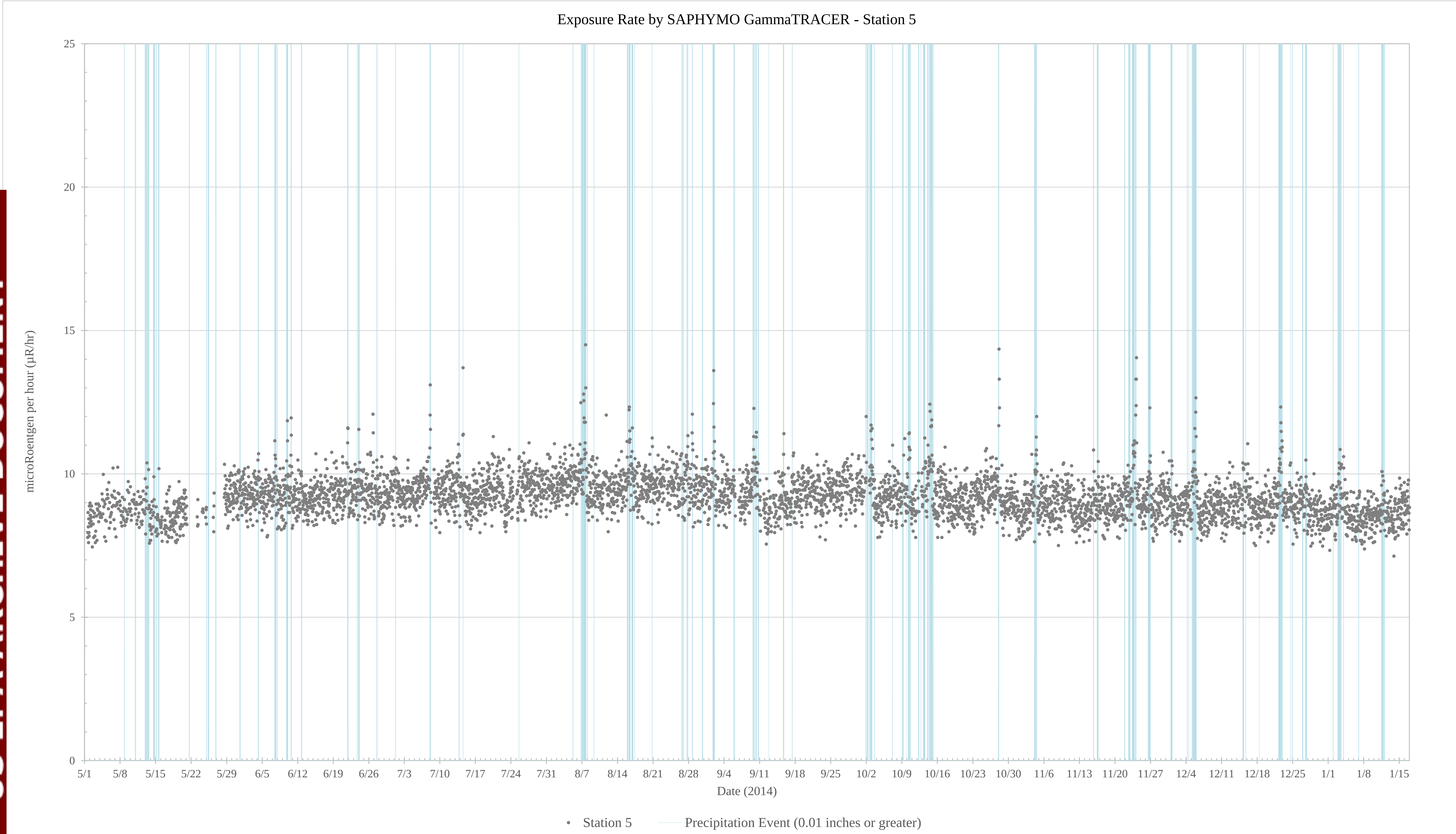
Exposure Rate by SAPHYMO GammaTRACER - Station 2





Exposure Rate by SAPHYMO GammaTRACER - Station 3
microRoentgen per hour (µR/hr)
25
20
15
10
5
0
5/1
5/8
5/15
5/22
5/29
6/5
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
9/25
10/2
10/9
10/16
10/23
10/30
11/6
11/13
11/20
11/27
12/4
12/11
12/18
12/25
1/1
1/8
1/15
Date (2014)
Station 3
Precipitation Event (0.01 inches or greater)


Exposure Rate by SAPHYMO GammaTRACER - Station 4
microRoentgen per hour (µR/hr)
25
20
15
10
5
0
5/1
5/8
5/15
5/22
5/29
6/5
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
9/25
10/2
10/9
10/16
10/23
10/30
11/6
11/13
11/20
11/27
12/4
12/11
12/18
12/25
1/1
1/8
1/15
Date (2014)
Station 4
Precipitation Event (0.01 inches or greater)



Exposure Rate by SAPHYMO GammaTRACER - Station 5
microRoentgen per hour (µR/hr)
25
20
15
10
5
0
5/1
5/8
5/15
5/22
5/29
6/5
6/12
6/19
6/26
7/3
7/10
7/17
7/24
7/31
8/7
8/14
8/21
8/28
9/4
9/11
9/18
9/25
10/2
10/9
10/16
10/23
10/30
11/6
11/13
11/20
11/27
12/4
12/11
12/18
12/25
1/1
1/8
1/15
Date (2014)
Station 5
Precipitation Event (0.01 inches or greater)